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SOCIETY OF ENGINEERS

ESTABLISHED MAY 1854

Journal and

TRANSACTIONS FOR 1903

AND

GENERAL INDEX, 1857 TO 1903

EDITED BY

PERRY F. NURSEY

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The Council of the Society of Engineers invite original communications from Members and Associates, as well as from gentlemen who do not belong to the Society, on subjects connected with any branch of Engineering.

For any papers that may be considered sufficiently meritorious the Council may at discretion award one or other of the following Premiums, viz. :—

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The number and value of the Society's Premiums are decided by the Council according to the number of meritorious papers read during the year.

By the Rules of the Society, Members of Council are disqualified from receiving Premiums for Papers.

PREMIUMS FOR 1903.

At a Meeting of the Society, held on February 1, 1904, the following Premiums were presented, viz.:—

The President's Gold Medal to:

Douglas Mackenzie, for his paper on Motor Transport for Goods.

The Bessemer Premium of Books to:

Robert J. Thomas, for his paper on Road Maintenance and Administration.

A Society's Premium of Books to:

Albert Gay, for his paper on Mechanical Stokers for Electricity Generating Stations.

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ESTABLISHED MAY 1854.

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February 2nd, 1903.

INAUGURAL ADDRESS.

BY JAMES PATTEN BARBER, PRESIDENT.

GENTLEMEN,—To be the first Borough Engineer elected to preside over an engineering society formed forty-nine years ago, and to have one's name added to the list of distinguished men who have occupied the position of President of such society, is an honour which one is able to appreciate and to value highly; but to convey to those by whose goodwill the honour has been conferred a just conception of its appreciation, or to express sufficiently how greatly the distinction is prized by its recipient, *hoc opus, hic labor est.* If I do not attempt the task your generosity will acquit me of indifference to its object and will accept the thanks I now offer for your having elected me President for the forty-ninth year of the Society's life.

The number of members and associates is 503, which with 20 honorary members makes a total of 523, the highest number that has yet been on the roll. Considering the constant drain on the Society's numbers by death, removal, and other causes, the maintenance of so large a membership is evidence of the usefulness of the Society and of its value to those engaged in the various branches of engineering. But gratifying as the present state of the Society is, it will not justify any relaxing of effort for maintaining its prosperity. The well-being of the Society is not entirely in the keeping of the President, the council, or the officers; it is shared by everyone connected with it. Upon each member rests a responsibility to do his utmost to uphold its reputation and its utility, and to be active and earnest in whatever makes for its life. The quality of the life of an institution is determined by the activity of its constituents, and that of our Society will be higher or lower as it is influenced by our energy or our indifference. To be receiving benefit from the Society whilst doing nothing to add to its strength will assuredly drain away its vigour and diminish its vitality. Therefore, may I appeal to both members and associates to make the welfare of the Society a subject of continuous personal effort, and, by contributing papers relating to engineering practice and work, to impart useful information to their fellow members, for by the mutual exchange of thought on such subjects the Society's influence and utility may be greatly strengthened.

An engineer holding a municipal appointment has invariably an enormous practice. The subjects with which he has to deal extend over a range which may be said to have no limits, and he is never without either work or clients, for public work has no known termination. In describing the qualifications and the scope of such an engineer, an eminent doctor has stated with much humour and accuracy that, "there is an immense range of knowledge which the modern municipal engineer is expected to be interested and conversant with. The professions of the architect, the lawyer and the doctor are acknowledged to be sufficiently exacting and absorbing enough to tax the energy and capacity of the ordinary man. But the municipal engineer, to discharge thoroughly all the functions which representative bodies require of him, must be something of a lawyer and a doctor and a complete architect and engineer rolled into one. He is expected to be thoroughly acquainted with the voluminous enactments on public health, which have occupied so large a portion of the time of the legislature in the past quarter of a century; to be able to pick his way through the shifting quicksands of sanitary science; whilst in his lighter moments he must toss off designs for town halls, public baths, hospitals and bridges, and with all this find time for the multifarious details of the town surveyor and inspector." In bringing before you some observations on the work carried out in a municipality it must be noted that it is impossible to deal with the whole of the engineering works within the limits of an inaugural address, and therefore only those which seem to be of special interest will be dealt with.

ROADS.

The interest of the public in the roads of the United Kingdom has been increasing during the past 25 years; it may be said to have revived, if not to have commenced, with the use of cycles as a means of travelling, and it is, perhaps, to the enormous increase in the use of the roads by cyclists rather than by horse vehicles that the need for maintaining them in a good condition has been impressed upon road authorities. The introduction of motor vehicles for travelling and for the transport of goods will accentuate the need for good roads; and although there appears to be in some places a desire to repress the use of these conveyances, it is probable that the improvements which are being made therein will bring them into more general use, and that their increasing popularity will result in the relaxing of existing regulations as to weight and speed rather than in the placing of additional restrictions upon them.

During the period referred to, the necessity for the management and control of main roads being exercised by popularly elected authorities invested with larger powers for their improvement and maintenance, has been recognised in legislation on the subject. The Local Government Act, 1888, transferred the control of the main roads from the Justices in Quarter Sessions to the County Councils, established by that Act; whilst the Act of 1894 dissolved the Highway Boards and placed the roads formerly managed by them under the jurisdiction of the Urban or Rural District Councils. The effect of this legislation has been to bring the main roads under the control of authorities whose members are elected by the ratepayers, and to develop a greater interest in the proper maintenance of the great highways of the country. The newly established authorities have seen the necessity for proper and efficient supervision by qualified and experienced engineers and assistants, and a systematic organisation of the various works connected with the maintenance of the roads. The so-called surveyor—frequently a farmer or a local tradesman—with a salary of 80*l*. or 100*l*. per annum, out of which he was expected to provide a horse and trap, has almost disappeared, and his place has been supplied by a qualified district surveyor acting under a competent engineer. Under the new and more experienced management the condition of the roads has gradually improved. The soft stone, frequently used on account of its being readily and cheaply obtained locally, has been discarded to a great extent for material of a harder and more suitable character; the transverse shape of the roads improved; better drainage provided; and generally, the roads made in a more substantial manner and kept in better condition. The more extensive use of steam rollers for consolidating the material, the greater attention given to the breaking of the stones to a suitable size, and the more judicious use of binding material, have also largely contributed to the improved character of the roads.

The critics of road maintenance, whose views are expressed from time to time in the correspondence columns of the news-papers, advocate the use of small stones which are to "unite by their own angles" and render binding material unnecessary, quoting Macadam's method of consolidating and fixing the metalling used in coating roads. The size of the stones to be used in repairing a road must be determined by the amount of traffic passing over it; where granite or stone of a similar character is used stones broken so as to pass through a 2-inch ring are usually employed for roads over which the traffic is heavy, and a smaller size, down to 1¼ inch, for roads with lesser traffic. The use of stones whose size is within these limits is found to give satisfactory results, but stones larger than a 2-inch gauge are unsuitable, except for town roads over which very heavy traffic passes, as they produce rougher surfaces when wear has become perceptible, and the complaints then made by cyclists and others as to the "lumpy" character of the roads are not unreasonable. In districts where road material is obtained from gravel pits, special attention is necessary in order to prevent the use of too many small round stones, and of similar stones of too large a size, as neither kind can be properly secured in place in the road. Unless the majority are broken into angular pieces a loose surface is produced which quickly breaks up under the traffic, and, when wear has commenced, the surface is dotted over with projecting round knobs, over which horses are likely to stumble. It is difficult to see how the method of allowing the traffic to consolidate and fix the stones on a road without the addition of binding material can be justified. Though Macadam and his succcessors may not have spread such material among the metalling it was produced in the crushing and grinding of the stones by the traffic, and it was the production of small particles by this action of the traffic which resulted in the fixing of the stones forming the road surface. Until a quantity of fine material sufficient to fill the voids had been worn from the stones the strain upon horses drawing vehicles over the loose surface was the cause of much suffering and injury, whilst the cost of traction was greatly increased. Now that steam rollers are available for consolidating metalling the action of the traffic for performing that operation can be dispensed with, though the addition of binding material is a necesssity. Not that it is impossible to consolidate and reduce the stones to an even surface by rolling without a quantity of fine material, but the *fixing* of the stones can only be accomplished by filling the voids with suitable material which is the binding objected to by the critics referred to. In each cubic yard of road metalling the voids, which amount to about 50 per cent., must be filled before the stones can be securely fixed. It is evident that no arrangement of the stones will abolish the voids or even reduce them to such an extent as to accomplish this. If before the new coat of material is spread the old surface is lifted for a sufficient depth, a quantity of smaller stones will be loosened which, when the new coat is pressed among them by a roller, will occupy a portion of the voids between the stones forming the new surface, but will not so completely fill the spaces as to render the addition of finer material unnecessary. The determination of the quantity and the character of the binding material to be used necessitates a greater amount of judgment and experience than the casual observer would admit to be required; and it is probable that most of the roads said by the users to be always in a bad state, which cannot be due to the heavy nature of the traffic upon them, have too large a quantity of fine material in their composition. It is necessary for the engineer to exercise ceaseless supervision and vigilance, both before the coating of a road in order to eliminate the excess of fine material which in time is produced by the traffic, and, after the spreading of the metalling, to prevent the addition of too great a quantity for binding purposes.

Perhaps the ideal macadamised road, if cleanliness, smoothness and freedom from dust be considered, is one formed of tar macadam, a material used in many towns on account of its forming a comparatively noiseless road, impervious to wet and therefore easily cleansed. Unfortunately this material is not suitable for very heavy traffic and is more slippery than ordinary macadam; it would, however, form a surface on which cyclists and motorists could travel with great ease, but there is little probability of even a track being laid along our main roads for high speed traffic, seeing that the cost of replacing an ordinary macadamised surface with tar macadam would amount to from 2*s.* to 3*s.* per superficial yard.

In connection with the subject of macadam roads may be mentioned the utilising of slag from blast furnaces for road metalling, which has led to the disappearance of most of the huge heaps of slag accumulated during many years in the neighbourhood of iron furnaces, and the turning into a saleable and useful commodity of what had long been regarded as worthless rubbish. Also a useful machine to which the name of "scarifier" has been given, now much used for breaking up the surface of macadam roads. This machine performs the work much more effectively than, and at from one-third to one-quarter the cost of, hand labour.

For town roads with very heavy traffic granite setts, wood and asphalt, on concrete foundations, are the materials generally in use. Attempts have been made with varying success to form composite blocks, and, more recently, blocks with chippings of granite or other stone, or wood fibre, and asphalt. Nothing has, however, been produced which has proved so suitable in all respects as the materials above referred to. Setts made by running iron furnace slag into moulds are used in some northern towns, but they have not been found satisfactory under heavy traffic on account of their slipperiness, and the cavities which are frequently found in them resulting in the breaking and pulverising of the setts. In many roads in American towns pressed bricks made from various shales, and highly burned, are extensively used for carriageway paving; fifty-two towns having 410 miles of such paving, one as much as 70 miles and another 60 miles. Since Mr. J. T. Eayrs, M. Inst. C.E., brought the subject before the engineers to British municipalities, in a paper read before the Association of Municipal and County Engineers in 1897, bricks made in this country have been laid experimentally at Islington, in a road of very heavy traffic, and in another in which there was only a moderate amount. In neither case was the result satisfactory, the bricks being worn away in a few months to such an extent as to need removal. A few English brickmakers are still trying to manufacture a brick suitable for carriageways, and although it may not be possible to produce such as will endure the traffic in the busiest streets it is expected that bricks will be made which can be used in many situations in which granite is at present the only suitable material. For the principal streets through which pass in ceaseless streams omnibuses, cabs, heavily laden vehicles of every description, fast and slow traffic of various kinds, the choice must be made from the three materials before mentioned. The selection, however, is seldom made without an indication from some section of the public of the material with which it wishes the road to be paved, and trouble looms ahead of the authority failing to act in accordance therewith, for in such matters, as in most others relating to road surfaces and all work thereon, the public has its opinions and is accustomed to express them with freedom and confidence. Thus granite setts are condemned on account of the noise made by the traffic passing over them, and asphalt because of its slipperiness and the bad foothold it affords to horses, especially in starting with heavy loads. Wood is undoubtedly the material most approved by the public, whose demand for a noiseless pavement is not likely to be relaxed. Business is impossible and residence distressing in a busy street paved with material on which the traffic produces a continuous clatter. In crowded streets containing buildings in which the business of a great population is transacted the pavement must contribute as little as possible to the inevitable noise of passing traffic. Wood and asphalt are the only materials which approach the ideal of a noiseless pavement, hence they are adopted in the principal metropolitan streets, although in similar streets in provincial towns asphalt is little used. Until about twelve years ago yellow deal was the wood chiefly used for paving, but the introduction of the much harder jarrah from Australia led to the softer wood being to a great extent abandoned. Jarrah is now in almost universal use, although in several important metropolitan boroughs a large quantity of deal is still laid. There are other Australian woods which form good pavements, such as tallow-wood, blackbutt, blue gum, and forest or red mahogany, but if imported it is in quantities so small that supplies are unobtainable when required for street paving. Engwood from Burma and mora from Demerara have also been tried with success. In view of the enormous number of wood blocks used in this country annually, it seems remarkable that not more than two kinds of colonial timber should be imported in quantities. The development of an export trade in the timbers produced in British colonies is a subject which is worthy of careful consideration by the colonial governments, but at the same time it will be necessary to provide for the planting and cultivation of trees in order that the timber industry may be an enduring one, otherwise there is a danger that after flourishing for a time it may expire and leave the forests denuded of trees, unproductive wastes.

The noise produced by traffic has been reduced to some extent by the use of indiarubber tyres on light vehicles, but the rattle of heavier conveyances still adds to the discomfort caused by the hammering of horses shod with metal. The noiseless shoe has yet to be made, and there are doubtless many difficulties in the way of its production and adaptation; but there should surely be no insuperable difficulty in constructing the framework of vehicles and in attaching the springs so as to prevent, or greatly reduce, the noise made by the present mode of construction. It is scarcely reasonable that, metropolitan borough councils having provided the most noiseless pavement obtainable, vehicles should needlessly cause an amount of noise of which some at least is preventable. The London County Council having delivered the metropolis from street cries and similar objectionable rows might consider the possibility of carrying their work a little further by making a by-law against unnecessary noises made by vehicles.

The cleansing of roads has engaged the attention of inventors from to time; brooms, washers, squeegees and other appliances have been manufactured for which much has been claimed, but actual working has often proved to be worthless. Nevertheless there are two appliances which are most satisfactory, and invaluable for cleansing purposes, viz. the horse scraper and the horse broom, without which the work of street cleansing would be much more costly than it now is. The freeing of a road from semi-liquid mud or slop is a simple operation, but the removal during the day-time, from a road crowded with traffic, of the thin film of greasy material which causes horses to slip in the manner too well known, is a most difficult if not an impossible task. Owing to the extreme thinness of the material to be removed it is unaffected by any tool that can be applied to it, whilst any attempt to wash it away by first watering the road and converting the greasy substance into slop, might unduly interfere with the traffic, and would certainly be much complained of by pedestrians; although a shower of rain, which would have the same effect as the watering, being a natural occurrence, would evoke no comment. Limited as he must needs be by a regard for public opinion and convenience, the borough engineer has but one remedy available for a road in the condition referred to, viz. to make a temporary surface by a plentiful sprinkling of sand or fine shingle, and to thoroughly wash the road at night. Notwithstanding the nightly washing and thorough cleansing of the streets in the busiest parts of the metropolis, and the efficient staff of orderlies engaged in gathering up the filth during the day, dust is produced in large quantities in dry weather and dispersed so widely that the air is laden with a mixture of finely powdered manure and other debris from the streets. Indoors the presence of this material is made apparent by its deposition on every surface, out of doors by the suffering produced in eyes, nose and throat of those exposed to its action. The insanitary and offensive atmosphere produced by this dust tells more severely on persons whose visits to the crowded streets are but occasional, and who live away from the impurities which are here met with; possibly those in daily contact with it are less conscious of its effects, but the nature of the material is obviously so noxious that it cannot be regarded as non-injurious to them. The prevention of dust is without doubt of great importance in every locality, but in a crowded city, where despite all precautions impurities are largely produced by the countless operations carried on, every care is necessary to render the air as free as possible from solid impurities such as are given off from the streets. The patrolling of the streets during hot dry weather by vehicles, containing water to which a disinfectant has been added, specially adapted for distributing the contents in a fine spray, would probably prevent much of the dust which now causes nuisance—at least it seems worth a trial. Possibly, as the development of motor vehicles advances, a machine may be constructed which, whilst passing along the street, may, by exhaustion, carry up through a duct, whose lower end travels over the road surface, the dust and dry refuse, and discharge it into a suitable receptacle containing water. Several attempts have been made to construct a machine which would simultaneously sweep a road and convey the sweepings into a van ready for removal, and thereby save the labour of sweeping the material into heaps and transferring it from the surface of the road to the van by hand labour; the machines have been either too unwieldy or have had defects which made their adoption impossible. There is great need for a machine which will satisfactorily perform these operations, and the difficulties hitherto experienced in those depending upon horse traction for their working may perhaps be overcome by a steam motor.* The disposal of sweepings from metropolitan roads is becoming more difficult every year as shoots become scarcer. From some districts it is barged away and deposited on low-lying land, in others it is mixed with manure and other refuse and sent away by rail to farmers. In Islington, where from 124 miles of roads 31,000 loads are removed in a year, a process was in use for many years of washing the road sweepings in wash-mills similar to those used by brickmakers. From the sweepings from flint roads a good sharp building sand was produced, whilst from the combined sweepings from macadam and flint roads a sand suitable for plastering was obtained. In addition to the sand a large quantity of ballast was recovered which was used in making rough concrete. An attempt was made to separate the small stones with a view to their being used for spreading on the roads when in a slippery condition; it was found, however, that mingled with the stones were innumerable nails, pieces of glass and crockery with sharp edges, which rendered the material unsuitable for the purpose intended. The dirty water from the wash-mills contained a large quantity of mud which was deposited in the sewers into which it was discharged, and as the cost of providing settling tanks and the removal of the mud therefrom would have been too great to have enabled the process to be carried on economically it was abandoned.

REFUSE.

The collection and disposal of the domestic and trade refuse produced in populous towns, forms a large item in the annual expenditure of a municipal authority, and the work involved therein must be carried on with never-failing regularity from day to day, for the nature of the material is such that any breakdown which caused a delay of but a week in the work over a large area, would result in serious inconvenience to many thousands of the inhabitants and disorganisation of the working arrangements for several weeks subsequently. Like many other services which are performed for the public with a regularity of which it is scarcely conscious until the continuity is interrupted, the benefit of this work is insufficiently appreciated. In carrying out the work, one is impressed with the appalling waste which takes place in many houses, and the lack of care and cleanliness in disposing of the domestic debris produced therein, for which material thousands of people have so great an affection that they frequently refuse to permit its removal when the dustmen call on their weekly round of collection.

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* Since this was written a notice has appeared in a paper of a machine which has recently been tried at Leeds with satisfactory results.

Notwithstanding the progress made in sanitary knowledge, there are many towns in which the midden system continues, with more or less elaborate requirements of the sanitary authorities for the construction, covering and ventilating of these gehennas of filth and putrefaction. Lying in its septic tomb, the domestic garbage not infrequently has added to it the fæces from the household privy—even in places where the water supply is constant and abundant—and the whole remains until the time for its removal arrives. At such times, which, fortunately, are not many in the course of the year, the disturbing of the contents in the process of removal fills the air with noisome and pestilential reek.

The disposal of house refuse, which amounts to nearly a ton per head per annum, is to a great extent accomplished by destructors. This is an effective and inoffensive mode of dealing with a material which quickly becomes a nuisance. In the earlier installations the object was simply the conversion of the rubbish into a harmless form by burning in specially made cells, oombustion being carried on by natural draught. Subsequently, between the destructor cells and the chimney, a cremator was added in which the gases from the cells were more completely burnt by passing over incandescent coke or cinders. Numerous improvements have been made during recent years in destructors, and many are now burning a greater quantity of refuse per cell, and more effectually, than the earlier types, without causing nuisance in the neighbourhood of the shaft. These results have been obtained by improved methods of charging the cells, the application of forced draught, the provision of a sufficient supply of air to the cells, and the more perfect combustion of the gases immediately after being given off by the material on the firebars. It has now been satisfactorily proved that in a properly designed destructor refuse can be burned without the gases being passed through any intermediate furnace and without any nuisance being caused by smoke, dust, or offensive smells from the chimney, at a cost which varies from about 9*d.* to 1*s.* 3*d.* per ton for labour only.

At most works the heat from the burning of the refuse is used for raising steam for sewage-pumping, mortar-making, sawing, grinding, chaff-cutting, the production of electricity, and for other work. Tho weight of water which can be evaporated by the combustion of a pound of refuse varies according to the character of the material, but generally it would amount to from ·8 lb. to ·9 lb. from and at 212° F. In some hand-fired cells much higher results have been obtained. From the clinker—which, with the ash amounts to from 28 to 35 per cent. of the weight of the refuse—concrete paving, bricks, window heads, steps, and other articles are manufactured. Hydraulic machinery has been introduced for the production of the various concrete manufactures and is now used at several works. The concrete paving made from destructor clinker faced with granite chippings can be produced at about 2*s.* 6*d.* per superficial yard, and the use of this material effects a very large saving in the paving of footways.

The enormous quantity of smoke and fine dust which is scattered abroad during the removal of clinker in some installations is the cause of great nuisance in the works, and is especially offensive and injurious in any engine house which may be near the cells. To the prevention of this nuisance the attention of engineers should be directed, and there can be little doubt but that a remedy might be discovered, which would make the operation of clinkering easier and healthier than it now is, and would prevent the air in the works being loaded with dust to the discomfort and injury of the employees, whose work is of an arduous and trying character. Other improvements will probably be made in connection with destructors whereby greater economy in working, and the utilisation of a larger amount of the heat, will be realised. The mechanical feeding of the cells by a method resembling hand-firing, capable of regulation so that the material may be distributed in any desired quantities; the supply to the combustion chamber of heated air so as to effect the complete combustion of the gases; and the construction of dampers of a more enduring character, are matters which seem deserving of the attention of engineers.

TRAMWAYS.

The increasing population in large towns and the desire for a cheap and more rapid mode of conveyance along the roads leading therefrom than could be provided by horse trams, have caused investigation to be made by many corporations into other systems of traction applicable to tramways. In this country the examples of mechanical tramway traction were steam and cable, whilst compressed air had been tried and abandoned. On the tramway in Caledonian Road, Islington, cars propelled by compressed air motors were tried on two occasions, but they were taken off after running for short periods. Cars similarly driven are used in a few places on the Continent, and to some extent in New York, though not on the principal lines. This system has not been developed to the same extent as any of the electric systems, and it is doubtful whether it can be brought to such a state as will enable it to compete with either the overhead or conduit systems, either commercially or in efficiency.

The hauling of tram cars by steam engines attached thereto has been carried on for some years in North London, Leeds, Bradford, Birmingham, the Potteries and other places, along many miles of line in the aggregate; it has, however, been discontinued in the three first mentioned places, in two of which electric traction has been adopted, and it will probably be similarly displaced in other towns where it now continues to be used. The disadvantages of steam hauling are the excessive wear on the rails caused by the weight of the engines—8½ tons—the great space occupied by the car and the engine as compared with that taken by a car moved by any other power than horse, the nuisance caused by smoke and fumes from the engine, especially to passengers on the outside of the cars, and the great cost of working, which amounts to about 10*d.* per car mile, or about the same as horse traction.

Cars drawn by a cable placed in an underground conduit in the middle of each pair of rails have been extensively used for many years in America and Australia. The first cable tramway in this country was constructed on Highgate Hill, in the north of London; the cars commenced running in 1883 and the tramway is still worked by cable. Other tramways on this system, with many improvements, have since been made at Brixton, in South London, Birmingham, Glasgow, Douglas and Edinburgh. Since 1890, when the first cable tramway, about 5½ miles of track, was laid in Edinburgh, the whole of the tramway system there has been constructed for cable haulage.

There is now a length of cable tramway equal to about 50 miles of single track in Edinburgh, Portobello and Leith. The system has been very successful, particularly on steep gradients, and the cost of working less than by horse or steam traction, being about 6*d.* per car mile. The cost of construction is about 9000*l.* per mile of single track. Prior to the recent developments in electric traction no tramways were so satisfactory as those worked by cable, both in operation and economy. But the progress made in the application of electricity as a motive power seems to have checked the general extension of cable tramways, whilst in America overhead electric is partly replacing cable traction, and in New York and Washington, where cable haulage had been adopted in consequence of the opposition to overhead trolley wires, the underground electric conduit is being substituted. Yet cable tramways are far from obsolete, and in deciding upon the most suitable system of traction for a locality the cable would undoubtedly be considered, particularly if the gradients on the route were steep, the traffic heavy, and a service of cars at short intervals were required without overhead disfigurement.

The working of cable tramways has shown that horse traction can with many advantages be superseded, whilst the developments which have been made on the Continent, and in America and Canada, have apparently caused most corporations to regard electricity as the most suitable motive power for their tramways, especially as in the towns in which the subject has been considered electricity works have been established, or were contemplated, for lighting purposes.

The application of electricity for car propulsion has been made by means of accumulators, overhead trolley wires, underground conduit, and surface contact. Accumulators carried by the car to be driven is theoretically an ideal system, but its inseparable disadvantages render it inapplicable as compared with other modes of electric driving; the increased weight of the car through the two tons of dead load of accumulators carried therein, and the short life of the batteries, making the working of the system very expensive. Tried at Birmingham, Hanover, Hague, Dunkirk, Berlin and Paris, and abandoned at most of those places, with working expenses greater than other forms of electric driving, the unsuitableness of this system was marked at the International Tramways Union Congress held in London in July last, by the passing of a resolution emphatically condemning the use of accumulators on tramways.

The overhead trolley system has been adopted more extensively than any other, and having regard to the cost of construction being about 3000*l.* per mile of single track cheaper than the conduit, the expense of working no greater, and the efficiency equal, the authorities in most towns where horse traction has been superseded by electric have had good reasons for applying the overhead system to their tramways. Except at the junctions of the tram routes, and in the streets of large towns, the unsightliness of the overhead wires is, perhaps, with most people but a temporary offending of the vision, whilst danger from the falling of wires across the trolley wires and from the breaking of the trolley wires themselves, can be considerably reduced by the adoption of appliances and methods of construction which experience has now made available. Like the cable this system is in successful working on very steep inclines, 1 in 12 and even 1 in 9 not being too steep for safe working; it is a very cheap mode of providing rapid travelling, the cost of working being about half that of horse or steam traction; and it has advantages in working over the cable, viz. that the car can be moved either forward or backward and its speed increased at the will of the driver. Notwithstanding the popularity of the overhead trolley system, and the very satisfactory results of its working both in towns where the costliness of the underground conduit would have made the electrification of the tramways a failure financially, and in others of greater importance, as Liverpool, Manchester and Leeds, where this might not have been so, some authorities have decided to adopt the underground conduit as being the more suitable for the requirements of their towns. Thus the London County Council have selected it for their South London tramways, the Bournemouth Corporation for the tramways in the town, although the overhead trolley will be used in the suburbs, whilst in Birmingham the underground conduit is considered to be the only system which can be accepted by the Corporation. The immense network of wires at juctions and crossings, and the appearance of the poles, trolley, guard and span wires in comparatively narrow streets, being much more conspicious than in wide suburban roads, have no doubt been deemed objectionable and dangerous in crowded streets by the authorities who have preferred the underground to the overhead system. The doubt expressed by Professor A. B. Kennedy, F.R.S., in advising the London County Council, "whether any system of overhead wires can really be regarded as likely to prove a permanent and final solution of the traffic problem in a great city like London," shows that the decision of those who have refused to adopt the overhead trolley in thickly populated districts, traversed by roads crowded with traffic, has much more than sentiment for its support. Though the cost of construction on the underground conduit system is great, amounting to about 10,500*l.* per mile of single track, it has not prevented the adoption of the system in Paris, Buda-Pesth, Dresden, Brussels, Berlin, New York, Washington and other places. The cost of working is about equal to that of the overhead system; the risk of injury to gas and water mains through electrolysis is abolished by the provision of an insulated conductor within the conduit for the return current, the rails not being used as in the overhead system as returns. The slot rail is not likely to cause inconvenience to the ordinary traffic so long as the width of the slot does not exceed ¾ inch, but some difficulty may perhaps be experienced by the passage of mud and other solid matter from the streets into the conduit; possibly the remedy for this may be found in flushing the conduit by means of a water-van travelling along the track whilst discharging water through a pipe fitting the slot.

The surface contact, which is the most recent system of electric tramway traction, requires no overhead work nor underground conduit, the current being conveyed to the cars by an iron skate under the car coming into contact with cast-iron studs or contact plates fixed in the middle of the track and projecting slightly above the surface of the road. All the cables supplying current are underground, and the return current is conveyed by the tram rails. A few miles of tramway on this system have been laid at Paris and Monaco, and 5½ miles of double track at Wolverhampton were opened for traffic last year. The cost per mile would probably not exceed that of the overhead system, viz. about 7500*l.* per mile of single track. The introduction of the surface contact system is too recent for the formation of any opinion as to its fitness for general adoption; it is mentioned here as the newest form of electrical tramway and as being worthy of study and observation, for it may be that in some development of this system the electric tramway of the future will be discovered. The adoption of electric traction on tramways has brought about numerous improvements in the construction of the track and has afforded great scope for invention and design. By a careful study of the actual conditions obtaining with respect to the wear of rails, the operation of points, car wheels and other details, experience has been acquired which has enabled engineers to design more suitable forms of rails, joints, etc. The importance of well considered details and substantial construction is now recognised, and although in tramway construction engineers and manufacturers in America have had some years' start of those in our own country, and the American manufactures are admitted by some English engineers to be superior to our own, the knowledge of this should stimulate us to study carefully every detail of design, manufacture and construction, with a view to improvement and the production of work which is accurate, reliable and of the highest quality.

A reduction in the number of rail sections and the adoption of standard sections would enable manufacturers to supply quickly, and would prevent the delay and additional expense which must always be incurred when rails of a special section are ordered. There can be no need for a large number of sections of girder rails, and it may be expected that the Standards Committee which has the question under consideration will effect a great reduction in those at present listed.

In the construction of the track, one of the things to be avoided is the following too closely of the methods adopted on horse tramways; the action of electric cars being much more severe on every part of the rail necessitates a more rigid construction. Hence with the 45-feet and 60-feet rail lengths now in use, special provision is necessary for securing firmer joints, and, what is of equal importance, the careful bedding of the rails throughout their entire length on the concrete foundation, in order to avoid the springing and lifting of both rails and paving by the undulations produced during the rapid travelling of the cars. Similarly, in the manufacture of the various parts of the work, greater accuracy is needed, particularly in the special appliances such as points, junctions and crossings, in order that every part of the track may contribute to safe and smooth running and that time may not be lost during construction by the necessity for altering badly fitting parts. Too little regard is had for accuracy in tramway work, and the delay which is thereby caused in the laying and completing of the work in the streets, generally at points where traffic is greatly congested, results in unnecessarily increasing the cost of construction, and inconvenience to the public. The desire for greater speeds than are at present permitted on tramways will increase as the confidence of the public in the safety of the service advances, therefore neither engineers nor manufacturers can afford to have a reference made to any weakness or imperfection in tracks, brakes, rolling stock, or any of the appliances connected therewith, as a reason for withholding sanction to accelerated services.

Motor Wagons.

The haulage of heavy loads along the roads by motor vehicles has not yet received the attention it deserves of those who are interested in the cheap and rapid transit of goods. Apart from the question of railway companies' rates, it is obvious that the conveyance of larger quantities of goods at a higher speed than is practicable by horsed vehicles has many advantages, and the number of motor vehicles now in use for haulage purposes is evidence that this form of traction is gaining supporters. Manufacturers of these vehicles have had much to learn respecting them, and weaknesses and failures have been discovered during the tests to which the motors have been submitted; yet with commendable enterprise and pertinacity on the part of the designers many of the defects have been remedied, so that breakdowns are now much less frequent than in the earlier days of motor traction. The strictly regulated and exhaustive trials conducted with admirable skill and impartiality at Liverpool in 1898 and 1899 were of great value in indicating, in a manner which could have been accomplished by no other means, the requirements which must be satisfied if motor vehicles were to be of any use commercially. In the second trials, as in those of the year before, the vehicles were put to severe tests in manœuvring, climbing and descending hills, and in travelling along roads paved with various materials during runs of 35 miles on each of two successive days. The results were in every respect more satisfactory than in the first trials, the vehicles generally superior, and their working more regular and reliable. So great had been the progress made in the design and manufacture of motor vehicles that the judges declared respecting them, that " they can be regarded as having arrived at such degrees of mechanical excellence and efficiency that their use, in practical trade operations, will be attended with success and economy as compared with horse traction." The Aldershot trials of December 1901, also show that manufacturers have not ceased to give their attention to the production of vehicles which will endure severe tests and satisfactorily accomplish the work required of them. But the successful haulage of greater loads than four tons on four wheels at a speed of five miles an hour is rendered impossible by the legal tare weight of the motor vehicle being limited to three tons. The necessary adhesion for hauling greater loads cannot be obtained without exceeding this tare limit, and the opinion expressed by the judges in the Liverpool trials is in accord with the experience of those acquainted with the subject, viz. that a four-ton tare should be permitted in order that heavier loads may be carried by a motor wagon running on four wheels at a speed of five miles per hour. A similar conclusion was arrived at by the officers conducting the Aldershot trials. The opinion obtains generally that the development of motor haulage is greatly retarded by the present restrictions, and that, until they are relaxed, the benefit arising from the more speedy transport of goods by this system is withheld.

The use of motor vehicles for the haulage of materials on public roads is a subject which has a dual interest for local authorities on account of the reduction in the quantity of offensive matter on the roads, and the question of the amount of wear resulting from this form of haulage as compared with horsed vehicles. It is obvious that the rendering of roads less insanitary could be accomplished by the reduction of horse traction, but the effect of motor vehicles in wearing away or damaging a road surface which has been made capable of enduring heavy horse traffic has yet to be determined. The damage by traction engines is well known in certain localities, but that can scarcely be taken as accurately representing the effect of wheels which have been designed with a view to the smooth running of a motor vehicle, and at the same time causing as little injury as possible to the road. It is very desirable that the relative effect on a road of horse and motor vehicles, conveying heavy loads, should be determined experimentally, and this might be undertaken by the co-operation of a few road authorities and owners of such vehicles. A thorough investigation of the influence of wheels of various forms and widths of tyre, fitted to motors carrying different loads, also appears to be absolutely necessary, both in the interests of the road authorities and the users of motor vehicles, in order to arrive at what is best suited to all the circumstances. The information which would be gained thereby would be of great value in deciding many important questions connected with this subject.

SEWERS.

In comparing the sewers constructed half a century ago with those of a later date, the improvements which have been effected by a better knowledge of the principles affecting the flow of water, and the manufacture of materials most suitable for sewer work, is apparent. The chief consideration in designing the old sewers seems to have been that it was necessary to make them of a size sufficient to admit of men working therein, without regard to the importance of providing a proper channel for the flow of the sewage. In the older parts of the metropolis brick sewers, 4 feet 6 inches by 3 feet, with vertical sides and semicircular inverts and roofs, have been provided for a dry weather flow which would half fill a pipe 9 inches in diameter. In such sewers solid matter rapidly accumulates; but an example may be given of one similar to that above mentioned, whose faulty construction being remedied by bedding a line of channel pipes of 4½ inches radius on the invert of the sewer, encasing them in concrete and forming a sloped benching on either side, a satisfactory channel was obtained which, notwithstanding the low velocity of ·9 of a foot per second, with a depth of 1$\frac{3}{8}$ inch of sewage, carries off the whole of the sewage without any deposit other than a faint trace of sand which is scoured away by an occasional flushing. Prior to this work being carried out the invert of the sewer was covered with solid matter 6 inches in depth. The periodical removal of this filth was a costly and offensive operation, but since the invert was made self-cleansing no such expense has been incurred. The provision of an improved channel in an old sewer is not always effected so simply as in this instance, but the great height which our predecessors gave to their sewers renders it possible in most cases to carry out the work from the interior of the sewer, thereby avoiding the expense of opening from the surface for the entire length of, and breaking up, the sewer. In determining the velocity of water in sewers, no formula which involves the use of an unvarying coefficient is now relied upon, since it is obvious that friction varies with the material of which the channel is formed, and, therefore, that a special cofficient must be used for each material if accurate results are expected. Kutter's formula, which was constructed upon the results of most laborious experiments and investigations, may be relied upon, as it takes into consideration everything by which velocity is influenced, and recognises a different value for the effect of various classes of material. But it is manifest that to ensure the greatest accuracy the coefficient for a particular material must be specially determined. With shallow depths and low velocities this appears to be essential, and is illustrated to a certain extent by the case just mentioned, in which the velocity calculated by the coefficient adopted by Kutter for a glazed stoneware surface in perfect condition is 1·185 feet per second, whilst the observed velocity was ·885; the same coefficient used with respect to depths of 2$\frac{3}{16}$ inches and 1$\frac{1}{4}$ inch in the same channel, but with a greater fall, giving velocities which corresponded with those observed. In conducting experiments for the purpose of constructing a general formula or determining a modulus, the materials must of course be carefully selected and the apparatus and appliances prepared and fitted up as perfectly as possible in order to exclude every extrinsic influence. Conditions so nearly ideal as those obtained in such experiments are rarely, if ever, met with in actual work; therefore in using these formulæ or moduli, the engineer must be guided by the experience which has been acquired by his own observation, and he must modify them so as to apply them to particular cases. The acquisition of the experience which alone will enable him thus to use general formulæ and moduli is the engineer's *sal vitæ*, and unless he labours to investigate for himself the modifications to be made for special cases and materials he will often be at a disadvantage.

The advance which has been made in the manufacture of materials for the construction of sewers and drains is an indication of the knowledge and skill of those engaged in the clay-working industry of the country, for it is chiefly due to their unceasing energy, undeterred by difficulty and failure, that the engineer can now obtain the excellent vitrified ware with which to construct his works. Whatever may be said with respect to foreign rivalry in other industries, it may truly be asserted that in the production of all articles included in the term "sanitary goods," not only are the clay-workers of this country unequalled, but that their manufactures are not approached in design, variety, or quality, by those of the makers in other countries.

A serious problem confronting London and other large towns, whose rapid growth has rendered inadequate the existing sewerage systems, is the conveying of storm water from the area built over, and the relief from flooding through the overcharging of the sewers during heavy rainfalls. The neglect of sewer authorities to construct sewers for intercepting storm water from rising ground within their boundaries when it has been changed from open country to populous districts intersected with streets and covered with houses, has resulted in the flooding of the lower portions of the towns by the rush of large volumes of storm water at great velocity into sewers from which it should have been diverted. In other cases flooding is caused through the rainfall, which the sewers were designed to convey, having been taken at too small a quantity. The construction of sewers large enough to carry off abnormal rainfall is, of course, impossible; but the assumption that the quantity of storm water entering the sewers of a district is represented by a slight depth of rain over the whole area per twenty-four hours is likely to lead to the construction of sewers insufficient to carry off a heavy fall of rain not of an extraordinary character.

SEWAGE PURIFICATION.

The past ten years have been notable for the developments and discoveries made in the purification of sewage. So much attention has been directed to the work performed by bacteria beds that it seems desirable to re-state what is well known but in danger of being overlooked, viz. that a satisfactory purification of sewage from which the suspended matter has been removed can be obtained by broad irrigation and by intermittent filtration through land, provided a sufficient area of suitable soil is employed and the process properly carried out. Failure can generally be traced to the overworking of the land, improper laying out and subsoil drainage, unskilful management, or the interference of ignorant farm committees. The difficulty of obtaining a sufficient area of land for sewage treatment in convenient situations has led to the establishment of many experimental works whose success has been followed by the construction of permanent works for dealing with sewage by bacterial methods. Nor has the work been confined to the liquid portion of the sewage, the suspended organic matter has also been successfully treated, being liquefied by bacteria so that after the completion of the process little of the putrescible solid matter of the sewage remains. In the bacteriological purification of sewage three systems have been adopted: (*a*) contact beds which deal with the crude sewage from which large floating matter has been removed by screens, and the suspended heavier mineral matter by deposition in detritus chambers; (*b*) similar beds which are filled with the sewage after undergoing sedimentation in a tank in addition to passing through the screen and detritus chambers; (*c*) similar beds, with greater provision for aëration, to which the effluent from the tank is applied continuously by sprinkling.

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The application of crude sewage causes a speedy reduction in the liquid capacity of the first contact bed, and frequent periods of rest are required to prevent choking. Partial recovery is obtained during rest by the liquefaction of organic matter, but the complete choking of the bed by mineral matter must ultimately occur. The liquid capacity of the second contact bed is not affected to the same extent. This system accomplishes a satisfactory purification, and liquefies the organic solids in the sludge without the production of offensive smell, but it is more applicable to small districts, where a large area of beds can be cheaply obtained, than to large towns.

The method of dealing with the suspended matter by means of tanks in which are deposited the solids, both mineral and organic, which are of too light a character to be arrested in the detritus chamber, appears at present to be more generally adopted for treating this part of the sewage. It has the advantage of preventing the choking of the first contact bed in which the small amount of suspended organic matter contained in the tank effluent is readily liquefied, though the smell from the tank and the effluent is generally offensive. The liquid capacity of both first and second contact beds becomes reduced, periods of rest partially restoring it, but the useful life of the beds has not yet been ascertained; it is probable that after being in use some years the material will require cleaning or renewing.

The septic tank effects a reduction of some 25 to 50 per cent. of the total suspended matter in the sewage, there being no difference in this respect between an open and a closed tank, although with the latter there would be no nuisance caused by offensive smells.

Some remarkable results have been obtained by the continuous sprinkling of septic tank effluent on bacteria beds made deeper than contact beds, and constructed so that there is a continuous supply of air into the interior. Double the quantity of tank effluent can be dealt with on a unit area, and a very high degree of purification attained; a striking result of this method being the large amount of nitrates in the final liquid due to the abundant supply of air to every part of the bed.

The purification of sewage by the bacterial methods referred to has been in operation but a few years, yet such progress has been made therein as to remove the difficulty of dealing with sewage sludge and to render the obtaining of a sufficient area of land for filtration unnecessary, with which troubles many authorities were confronted. There is, however, much to be accomplished, and many investigations need to be made before our knowledge on the subject is complete; but the process being carried on in many places, information will be obtained by numerous observers which should lead to a more perfect understanding of the life and work of the organisms by which the purification of foul organic matter is effected, and the adoption of such methods of construction as will provide the most fitting environment for their development, and enable them to carry on their work with the greatest success attainable. A pleasant feature in connection with this subject is the friendliness which has characterised the association of engineers and chemists engaged in both experimental and permanent works for sewage treatment; it is to this, as well as to the observation and resource of members of both professions, that the present position of the question is due, and the maintenance of this happy relationship in prosecuting the work still remaining to be done will greatly assist the further development of this important process.

A cordial vote of thanks to the President for his Inaugural Address was proposed by Mr. Percy Griffith, the immediate Past-President, seconded by Mr. Nicholas J. West, Vice-President, and carried by acclamation.

The vote of thanks was duly acknowledged by the President, Mr. J. Patten Barber.

March 2nd, 1903.

J. PATTEN BARBER, PRESIDENT, IN THE CHAIR.

TOPICAL DISCUSSION:

ROAD TRAFFIC IN AND NEAR LARGE CITIES.

INTRODUCED BY W. WORBY BEAUMONT, PAST-PRESIDENT.

THE PRESIDENT said that on the present occasion the Society would depart from its usual procedure, inasmuch as there would be no written paper to introduce the discussion. A valuable suggestion was made a year or so ago that the council should introduce a discussion on some popular subject in order to see whether it would prove interesting to the members of the Society. They considered themselves fortunate in having secured Mr. Worby Beaumont, a Past-President of the Society, who had kindly undertaken to open the discussion, the subject being "Road Traffic in and near Large Cities."

Mr. W. WORBY BEAUMONT: Mr. President and gentlemen, as you say, Sir, we are trying something that is new in procedure to-night, and its being new must be my excuse for having put more points in the synopsis of my introduction of the discussion than I now find it necessary to deal with. I realise that there are points that I need only touch upon in order that they may be dealt with in the course of the discussion.

In my address as President of the Society in 1898, I referred to the difficulties that were even then proved to be almost impossible of avoidance in the conduct of traffic, not only in London but in other large cities, and I then mentioned various things that would have to be reckoned upon as absolutely necessary. I referred to the objection to the use, in crowded thoroughfares, of tramways, and to the possible use —though then not quite a practicable one—of motor vehicles for conducting much of the traffic which is at present conducted by horses. I propose presently to refer to the remarks I then made, but I will now proceed to deal with a few points.

Firstly, the difficulties in great cities. We may say that the one great difficulty is the "not-room-enough" difficulty; and that is the greatest of all, and the one which seems to be almost insuperable in cities where this traffic is in streets that are not wide and that are amongst buildings of the vast value of those in different parts of London. In fact, the difficulty of providing for the making of new streets, or even the widening of streets, in most parts of the city, is that it would take nearly the money of a nation to buy the necessary property. Where the ground is worth pounds per inch of frontage of little depth, it would seem folly to talk about Haussmannising the city, and buying that ground and throwing it open for use as roads.

Of course, a good deal could be done like that which has been done perforce in New York. As they are unable to spread out laterally, they have gone up vertically; but the objections to that are so very many, that one needs only to refer to them to dismiss them.

To some extent the growing evil will cure itself. With continued increase of passenger traffic into and through London, much of the business that now brings thousands of vehicles —light and heavy—into the streets will become impossible. The business will be strangled by its own growth, unless increase of cost of conducting it sends the business establishments away out of the cities, as it has sent many manufacturing trades already.

The question arises, then, if in certain parts of a great city the value of the property is so great that it is almost out of the question to consider the making of new roads, can the roads themselves be by any means improved in traffic-conducting capabilities? I have seen, quite lately, in some papers dealing with this matter, the suggestion that, if it were not for the vehicles of different kinds standing at business places—warehouses, offices and shops—even for a short time, the streets would be able to conduct a very great deal more traffic. But I am afraid that we must not rely upon that sort of objection, because we must remember that, were it not for these business establishments, there would be very little reason for many of the people to go into these cities, and very little reason for the traffic that fills the streets in such cities. It is because of the existence of these very buildings, and what they do and what they sell, and what people want to learn in them, and so on, that the traffic is brought about. We have to recognise that it is impossible, in fact, to get rid altogether of the vehicles that stand outside business places. Close the business premises along the main routes of traffic, and how many people would there be in those streets? Prevent the vans and carts from standing to deliver or take up their loads, and how much business would be done? Refuse to allow carriages to stand outside shops, and how many of the best shops could remain open? These places are the very origin of the business of the traffic, and of the prosperity of a city. The penny passengers in the crowds of omnibuses do not count in comparison—omnibuses, each with two horses, with eight iron-shod hammering hoofs, breaking up the road surfaces, for which the omnibus companies pay nothing. "Send the standing vehicles into side streets," some people say, but I would like to know where the side streets are—in London, at all events—where there is any room to put vehicles that are waiting to receive parcels or waiting for someone who has gone into a shop, say either in Cheapside, or down by the Bank, or in Cannon Street, or any of these places.

As far as I can see, at present, the only way to deal with these streets that are too small for the great traffic that they have to carry even at the present time, and for the greater traffic, as we see must be there before long, is to increase the average speed of the vehicles that go through the streets. The average speed cannot be very well increased until we have :—

Firstly, given to the police authorities more power than they have at present to deal with the traffic and the different kinds of vehicles, particularly the slow traffic, and to deal with the drivers of that traffic. Some time since the Chief Superintendent of Police sent out certain notices that drivers were expected to observe their proper positions in the streets, and to keep their position on the left as near to the kerb as possible; in other words, that they were to waste less of the street than they are in the habit of doing. But those notices were simply sent to the various police stations, and there they hang up amongst others, and sometimes behind a door and elsewhere out of public sight. Hardly anyone knew anything about them, and, when questions were asked about them, it was found that the police have no power, or very little power indeed, under which they can exercise the control which is absolutely necessary if we are to get more vehicles through the streets than we get through them now.

Secondly, if we give to the authorities that further power, then we next come to the increase of speed which will be made possible, partly by the improved regulations, and partly by the gradual introduction of mechanically propelled vehicles instead of the horse-drawn vehicles; partly because they will take up very much less room, and partly because they are easy of control and can be manœuvred into narrow places so much more quickly than other vehicles.

I am saying nothing whatever on this point as to the advantages from other considerations, such as the insanitary condition of the streets and so on. I am dealing with the question of getting the traffic through, and preventing the enormous waste of time that occurs in this part of London and in other towns by the blocks that hundreds of people—thousands I might say—are kept waiting minute after minute throughout the day-time, which must be reckoned at many thousands of pounds a day. None of those other things I mention, except as further points forcing upon us the desirability of snatching at any of the little improvements that we may make for increasing the average speed at which we can get the traffic through the streets.

I have said that to increase the width of the existing streets, or to provide new ones, in the central part of a city like London seems to be impossible; but that, of course, does not obtain with regard to those parts that are not actually in those very valuable centres. We see that elsewhere the making of new thoroughfares, such as the London County Council are now making from the Strand and elsewhere, is possible; and, great as the cost is, we know that they must be made. In some cases the expenditure is largely recouped by improved values of the new sites. The different things that have been proposed, such as arcades and overhead footways, only offer very partial help. The growth of a big city, its development by the changes that have converted a centre which had, at one time, a resident population, into one which has only business places along the main thoroughfares —the conversion of all the places between those thoroughfares where formerly there were cottages and houses, many of them with gardens round them, into these busy hives—has brought about this immense density of traffic in the centre, and all the growth since has been by processes of accretion along the lines of the few thoroughfares that were formerly sufficient for the smaller towns.

Now the main thoroughfares out of London, with the exception of two or three—and one could count them nearly all on one's finger ends—are only those that were necessary a hundred years ago. In fact, while all the land between the main thoroughfares near London and in the suburbs has been gradually covered, and has produced more and more traffic to be put upon the main thoroughfare, there is not one single main road that has been improved. In fact, many near London have not only not been improved, but have been encroached upon, with the result that London is now like a vast india-rubber bottle which has grown and grown in every respect except at its neck. The result is this tremendous congestion which everybody is now complaining of—a congestion which will make business before very long almost impossible if the growth of traffic goes on as it has gone on in the last few years. I say therefore that, tremendous as it may seem, we shall have to look steadily in the face the great want of what I may call the Haussmannising of London. The work that is being done now in the Strand gives some idea of what may be done. The County Council now has under consideration an expenditure of something like eleven millions, of which something like five millions will not be recouped by the improvements, the sale of land, and so on. Well, if the traffic is growing to such an extent that it is beginning to prevent itself from being carried on, surely it must give us an argument for saying that there must be something behind that traffic sufficient to provide means to make it worth while to consider the payment of the interest on the capital necessary to carry out the work.

The London County Council is doing a great deal of splendid work in that way now, and I hope that it will continue to do it, and not always do what it has done in several places in the Strand—namely, having obtained a splendid wide street along a business thoroughfare, where horses and the various vehicles used for business purposes must have a stand, throw 19 feet off that expensively obtained road into pavements, where a pathway of 12 feet would be ample. That makes a very pretty plan on a drawing-board, but it does not secure the space for the vehicles which might be obtained, and it robs the roadway of the whole width of a line of vehicles which might have been had for nothing.

I said in 1898—and many people, I believe, agree with me—that, valuable as tramways are outside cities, they are an unspeakable nuisance in those streets that are narrow and which have very heavy traffic. The cars are tied to a line. That iron rail is a metallic admission of the badness of the rest of the road, and those cars can only move along that line; and, if any vehicle is standing by a business place, no other vehicle can pass by; and, if there is anything crossing to the other side of the street, the car has to stand, and everything else also that wants that road has to stand. In many places a wheelbarrow is sufficient to cause a block because the tramcar is unable to accommodate itself by moving a foot or two from its hard and fast line.

Where, then, the traffic with ordinary vehicles is very heavy, the tramways should not be permitted; although we have been very glad in the past to have the greater carrying power of the tramway because of the smoothness of its road. And so we must hope that in the future, we shall be able to get rid of these tramways and recognise them as valuable in other places, that is, where they can be laid and used as what they are, namely, railways.

I have before me a cutting from a newspaper that deals with matters of this kind very frequently, complaining that three tramcars on certain roads out of the western side of London were recently seen standing because a butcher's cart containing a few chops and a bundle or two of sausages was stopping on the side of the road to deliver these things. It goes on to say that this is a monstrous anomaly. Now, inasmuch as the houses were there before the tramways and before even the roads or the pavements were made, and as the householders on such roads have some rights that people in a tramcar cannot have, the "monstrous anomaly" lies in the use of a tramcar in such a road. The requirements, moreover, of the people in those houses, whether of a few shillings' worth of chops or standing room for a doctor's trap, are to them just as important as the penny ride to the people inside the car on the iron rails that should not be there; and those three cars would not have had to stand there and block all the rest of the road if they were not on this hard and fast line.

The question arises whether every other kind of traffic is to stand aside on the narrow roads because of the existence of tramways which should not be necessary, or whether the people who live on those roads are to go without all their requirements because of these tramways, and whether the tramway is to give way to something that is amenable to the conditions of the traffic. That remains to be seen. But I certainly think that we must look forward to the time when, instead of having to put down strips of iron in our streets and suburban roads, so as to reduce the rolling resistance of the vehicles, the roads shall all be made better, and, what is equally important, better maintained, and then rails will not be necessary.

Now, coming to the question as to traffic near the great cities, we must remember, when we deal with this question, that the outlying districts of to-day become the suburbs of to-morrow; and that if the growth of the population of all those areas between the roads, which formerly were parks and grounds and fields which are now covered over, continues—if this growth of the suburbs and filling up of all the spaces in between, making more and more a network of roads for delivering traffic into the main roads, and requiring materials from along those main roads, still goes on, we must certainly call for the establishment of some authority which shall have power to see that the plan of these future roads, roads through property not yet developed, shall be so designed that those roads shall help to carry off the traffic and increase the carrying power of the existing roads: that is to say, that they shall be so placed that they shall afford some relief to the existing roads. At present these suburbs grow without any reference to this question. The result is that we have that which may be likened to a vast growth of branch and supply pipes of a great water-supply—an immense increase in the number of all the branches, and no increase whatever in the main pipe, with the result that branches are unable to get their supply because it is impossible that the supply which those branches require can pass through the main.

It will be noticed that, inasmuch as a place like London, or other big city, grows in most radial directions, the rate at which the traffic grows is in some proportion to the square of the increase in the diameter of the city; but as the distances to which people and things must go or be carried increases, and as the use of vehicular means increases, the growth of wheeled traffic is greater than the increase in the population. Hence the necessity for a proper supervision of the laying out of these new districts is becoming more and more pressing. But at the present time the growth is allowed to continue without any supervision, just as in all time that has gone.

Amongst other people who are doing their best to bring home to everyone the gravity of this question of traffic on roads generally, is the Roads Improvement Association, through whose instrumentality the Local Government Board is about to hold an inquiry: "To inquire into the general condition and sufficiency of the roads of England and Wales, and to report whether any, and if so what, amendment of the law relating to these matters or its administration, is desirable in view of the various purposes for which the roads now are, or shortly may be, utilised, and particularly whether any change of the authorities who have control over the roads or of their powers is required." It is, moreover, very satisfactory to know that the Royal Commission which has been formed is to take into consideration not only railway communication round about London, tubes and other methods, but is to consider the methods of communication by wheeled vehicles on the surface.

This fact—the fact that we have secured these helps to the consideration of these matters—is, of course, very encouraging, but it remains to be seen whether the interests of those who are not represented by the railway, the tube and the tramway methods will have a proper representation on this commission: and it is to be hoped that none of those who are concerned in this matter will continue to assume that it is everybody else's duty and not their own. Every year that passes, more and more difficult, and more and more expensive, must become the inevitable improvement and extension. Hence, what one wants is to see that it is not left to a few people to urge these matters, but that it shall be recognised by everybody that, though there may be some increase for the time in the cost of rating for road improvements and road maintenance, in the end the cost will be lessened and everyone will be so much the better off for having undertaken these expenditures while they may be done with the least loss.

It is not so very long ago that the old fallacy with regard to turnpikes was reigning, and it was generally said, "Why should we pay for the roads? We do not use the roads. Let those pay for them who do use them." But a wiser legislature said, "No, that is not true. Everybody uses the roads, directly or indirectly." The carrier who delivers goods from towns to villages, or from one place to another, pays his turnpike—he pays, we will say, 4*d*. He carries a dozen parcels and delivers them at a dozen places; and he, of course, at once said, "I cannot pay that 4*d*., somebody else must pay it," and he put a penny on every one of the twelve parcels; and hence made a profit on turnpike fees. Everybody uses the roads directly or indirectly, and in turnpike days most people paid more for them than they do now with a general rate. That was recognised, and the result was the Turnpike Act. We all know how very much better the roads have been since that and other changes have taken place; and we ought now to recognise that to place the roads in the hands of authorities, who have the power to carry out uniform methods of construction and of repair is a desirable thing.

I would like in conclusion to draw your attention to the following summary of the reforms in the existing system of highway administration suggested by the Roads Improvement Association.

1. The creation of a separate Highway Commission or a new department of the Local Government Board, which shall be a supreme Road Authority, advising and supervising the local authorities in all matters relating to roads and their maintenance; and which shall have power to take action in cases where the local authorities neglect to carry out efficiently the highway duties entrusted to them.

In addition, the Highway Commision should be entrusted with powers requiring and enabling it—

(*a*) To administer a government grant in aid of the maintenance of existing main roads.

(*b*) To administer a government grant in aid of the construction of new main roads of national importance.

(*c*) To administer a government grant in aid of the construction of (1) loop roads suitable for rapid traffic round small towns and villages, and (2) new and properly engineered roads over or around dangerous hills.

(*d*) To determine which roads shall be classified as main roads. (The Royal Commission on Local Taxation recommended that "some authoritative and impartial body should revise the distribution of the main road grant and decide what roads should be main roads alike in Counties and County and Quarter Sessions Boroughs.")

(*e*) To prescribe and administer regulations with respect to the qualification, appointments, duties, salary and tenure of office of road surveyors and municipal and county engineers.

(*f*) To report to Parliament upon all tramway schemes promoted by way of bill in so far as they affect the public roads.

(*g*) To report upon all light railway schemes when it is proposed to lay the whole or part of such railways upon the public roads and upon all tramway schemes promoted by way of provisional order.

(*h*) To prescribe and administer regulations with respect to the width of roads and methods of road construction.

(*i*) To ascertain by experiment and enquiry, the best and most economical methods of road maintenance and repair, and to advise the Local Authorities accordingly; and

(*j*) To prepare and present to Parliament an annual report upon the construction and maintenance of roads in England and Wales.

2. The payment out of Imperial Taxation of one-half of the cost of the maintenance of main roads in England and Wales.

(In 1888, 498,597*l.* (or half the cost) was voted by Parliament as a grant in aid of main roads. On the passing of the Local Government Act of 1888 this grant ceased to be voted annually, but certain revenues were assigned to the local authorities in lieu thereof. At the present time the unappropriated balance of the Exchequer contribution accounts of the county authorities may properly be regarded as the grant from the Imperial funds in aid of main roads. In addition to the revenues now collected by the Imperial Government and assigned to the local authorities, the Royal Commission on Local Taxation have recommended that a further grant of one-half of the expenses of the maintenance of main roads should be paid out of the Imperial Exchequer. They estimated this grant at a little over 1,000,000*l.*)

The distribution of the grant should be governed by the following considerations—

(*a*) The grant should be paid in respect of the principal roads in London and in the county boroughs as well as in respect of those in other districts.

(*b*) The grant to be strictly conditional upon efficiency, and to be paid over in those cases only in which the local authority obtains a certificate stating that its roads have been maintained to the satisfaction of the Highway Commissioners.

(*c*) The urban districts and non-county boroughs to share in the grant only when they hand their main roads over to the county authority for maintenance.

3. The payment out of Imperial Taxation of one-half the salaries of road surveyors and municipal and county engineers.

4. The enactment of provisions which would enable His Majesty in Council, upon the recommendation of the Highway Commissioners, to approve of schemes constituting Highway Authorities having jurisdiction and rating powers over large areas.

(This provision would enable, for example, a single Metropolitan Highway Authority to be constituted for all the principal roads within a radius of 25 miles from St. Paul's, or such other area as, after local enquiry, the Highway Commissioners should deem to be expedient. It would also enable a single Highway Authority to be established for the main roads in Lancashire or Lancashire and Cheshire, such an authority to be composed of representatives elected by the County Councils and the County Boroughs.)

The Highway Authorities thus constituted to have power to vary and determine the direction of all new streets, and to be under obligation to draw up schemes for the development of the districts under their control, to which all those engaged in building operations and the planning out of building estates will be required to conform; so that as the cities develop, new main roads parallel with and alternative to the existing ones will be formed.

(This will have the effect of placing some limit upon the enormous expenditure which now has to be undertaken by the large urban districts on account of street widenings, street improvements and the removal of insanitary areas.)

5. The adoption of provisions which would enable the county or main road authorities, with the sanction of the Highway Commissioners, (1) to undertake the maintenance of the district roads, or (2) to combine adjoining urban and rural districts under a joint committee for the purpose of the maintenance of the district or ordinary highways.

6. The simplification of the machinery whereby land is taken for the purpose of road construction and widening.

7. The enactment of provisions enabling the Highway Commissioners to exempt, on due cause being shown, a local authority from the operation of Section 92 of the Lands Clauses Act.

(This would enable a local authority, for example, to take part of the front gardens of a row of houses for the purpose of a street widening without having to buy the entire property.)

8. The enactment of provisions making the Highway Authorities liable in damages for loss or accidents directly due to any neglect on their part to carry out their statutory obligations to maintain the roads in an efficient state of repair.

9. The consolidation of the Highway Acts.

As bearing upon the improvement of main roads in and near great cities the following may be quoted from a letter from the Roads Improvement Association to the Right Hon. A. J. Balfour, M.P., before the appointment of the Local Government Board departmental inquiry and before the appointment of the Royal Commission on the broader question.

"The Council of the Roads Improvement Association, an incorporated body representing the general public in its capacity as road user, have been giving serious attention to the congestion of traffic upon the existing main roads, especially those in or near the large urban districts, and they desire to direct your attention to the following condition of affairs:—

"1. The suburban areas of the large towns are being built over without reference to any general design under which new main roads would be formed, with the result, that these areas are little more than a chaos of short mean streets, which take no share of the through traffic and serve only to feed the few main arteries which existed at the beginning of the last century. It is impossible to modify the resulting evils by building new trunk roads, for when the turnpike system was abolished no alternative machinery was provided for the construction, either by public or private enterprise, of new arteries of traffic through and out of the great towns.

"2. Under the existing system of Highway Administration, the care of the roads is divided up among so many authorities that it is impossible to obtain a uniform system of management, with the result that although large sums of money are spent upon the maintenance of our roads, their condition leaves, in some cases, much to be desired. There are many instances in which a main trunk road in the course of twenty miles is administered by no less than ten or twelve different authorities. Some improvements were made by the Local Government Acts of 1888 and 1894. In particular, the County Councils in many districts have done much to improve the roads, but the usefulness of the County Councils would be increased largely by an extension of their powers in highway matters.

"The system of Highway Administration is closely bound up with the housing and transport questions; and a large number of members of the House of Commons are of opinion that the time is now ripe for a public inquiry into the existing system, with a view of ascertaining what legislative and administrative alterations economic changes have rendered necessary."

That is to say, even if the existing authorities recognise the necessity of these improvements, which everybody admits, the powers are wanting to enable the district authorities concerned to carry them out.

With regard to the character of the surface of the streets, here is a valuable article in 'The Edinburgh Review,' of January, 1903, referring to the character of the roads in France, and comparing them, I need hardly say to our disadvantage, with the roads of many parts of England. The writer says: "No effort is made, as in France, to adjust the quality, gradients and width of a road to the average traffic that it has to bear. On the contrary the main roads leading out of London are among the worst in the country. Narrow, ill-surfaced bottle-necks, which would not be tolerated for a day in any Continental capital." He also says, speaking of motor-cars, "Many of the best grounded protests against motor-cars are based not on any faults of the vehicles themselves, but on the conditions of the roads over which they have to run."

Here I may add that the Thames Embankment road is one of the worst in London for a great part of every year, solely because, though it is frequently re-made at enormous expense, no proper system of mending is maintained, hence the badness and the cost.

So far, then, I have touched on only a few of the matters that are included in the synopsis of my paper; but I think, gentlemen, that whether you be cyclists, or merchants, or millers, or automobilists, or whether you feel interested in any one of the methods by which at present you or your materials are moved from place to place, or have to fight your way from the suburbs into a city like London, or from that city into the suburbs, you must recognise that it is now time for strong persevering efforts to be made towards the construction, where possible, of new main thoroughfares, and towards the obtainment of something like order and system in the laying out of new roads in districts that are now to be opened up, and which could help to carry the traffic, instead of helping, as they have done hitherto, only to increase the difficulty of carrying on the traffic upon roads that already exist.

In order that those who wish to go into this question, or to have before them anything that has recently been produced upon the subjects that I have touched upon, may be able to do so, the Roads Improvement Association has been good enough to let me have a few of the pamphlets that they have recently published dealing with the question under consideration. They are here, and are at the disposal of those who wish to have them. Further, Mr. Rees Jeffreys, the honorary secretary of that association, has sent me a few copies of a map showing the lines along which it is proposed that certain new main radial roads should be made from London, extending out into the different parts of the country, or the lines, at all events, along which it is possible to make them, where at present there are only the old roads which have been without any improvements, I may say, for a hundred years. There are also plans showing proposed new roads that would enormously increase the facilities by which one can go from London to Slough, Windsor, Reading and Bath, without going through congested areas.

[These documents were distributed at the meeting.]

The PRESIDENT said that he had very great pleasure in proposing a vote of thanks to Mr. Worby Beaumont for the very valuable contribution which he had made to the discussion.

The vote of thanks was carried by acclamation.

The PRESIDENT (continuing) invited the members to take part in the discussion, but to confine their remarks to the subject under consideration as closely as possible. He would ask them to avoid the two questions of motor transport and the maintenance and administration of roads, because papers had been arranged for dealing with those subjects and which would be read later in the session.

Mr. HENRY CONRADI said that he had collected some statistics bearing on the subject of the discussion. He reckoned that, roughly, one mile of tramway line cost from 3000*l.* to 5000*l.* The maintenance per mile of ordinary roads of a width of about 40 feet ranged from 30*l.* or 60*l.* up to 90*l.* In Kent it reached to 112*l.* and 200*l.* per mile, due to heavy traffic and densely populated areas near great towns. If motor-car traffic was used, they would have either to make new roads or to render the roads stronger than they were now. The main roads in England and Wales extended to about 25,700 miles. In Scotland there were over 22,000 miles. All those roads had to be put in repair and to be strengthened, to render them able to carry motor-cars, for goods traffic up to 4 or 5 tons, or for passenger traffic of about 1½ to 2 tons. We had at the present time in the United Kingdom 1483 miles of tram-lines opened, and 7752 cars at work. The number of passengers carried per annum by the tramcars was 1,394,452,983. The number of miles run by same, 145,127,423. He was not much in favour of the slow omnibus service, but he was a great friend of tramways, and had been engaged upon them for many years. The horse omnibuses running at the present moment were 1368 in number. The passengers carried by the omnibuses per annum were 209,462,000. The miles run were 32,628,900. The horses at work were 16,772.

In the provinces one tramcar carried on the average from 50 to 60 passengers. At Blackpool the tramway cars carried from 54 to 95 persons, and in the holiday time they carried up to 150 passengers per car. In order to decide whether the present traction service should be transferred to motor-cars, the different capacities must be compared. A tramcar fully loaded, running on rails, weighed from 8 to 10 tons. A horse omnibus fully loaded, carrying about 26 passengers, weighed about 2 tons. A motor-car carried from 2 to 4 passengers, if it was a private vehicle, weighing about half a ton. A motor omnibus, carrying from 9 to 12 passengers, weighed about 2 tons fully loaded. While a tramcar drew a profitable or paying load of about 4 to 5 tons, a motor-omnibus would carry only a paying load of about half a ton, and a motor-lorry fully loaded would carry a paying load of about 2 to 2½ tons. How many motor-cars would be required to provide for the transport of the number of passengers which he had referred to? While a motor-car omnibus carried about 12 passengers, the tramcars averaged 60; consequently, there would be required at least five times more motor-cars than tramcars to satisfy the traffic. Therefore, about 38,760 motor-cars would be required to replace the tramcars and 2736 to replace the omnibus service, making a total of about 41,500 motor-cars for both services, irrespective of the lorries for goods traffic.

Then the question arose, if all these motor-cars ran in the streets, would the movement of the traffic be easier than it was now, and would there be sufficient width for ordinary traffic to be accommodated besides? He thought that there would be a congestion caused by the motor-cars, which would necessarily have to do exactly the same work as the tramways were now doing. There was an excellent motor-car service from Cricklewood to Oxford Circus, carrying 12 passengers a distance of 4 miles. A horse-omnibus on the same line went at a speed of 5 to 6 miles an hour. The motor ran about 8 or 12 miles an hour. It could go more quickly, but the traffic was often congested. There was about 10 or 12 minutes' difference between the time the horse-omnibus and the motor-car omnibus took for the same distance. He was sorry to say that he observed every week breakdowns of the motor-car omnibuses. Up to the present time they had not come to such perfection as was required to make a reliable service of motor-cars either for passengers or for goods. Personally, he preferred steam to petroleum motors. There were steam motor-cars. He did not know how reliable they were, as he could not get the information he required. The petroleum used in working motor-cars gave out a very unpleasant smell, which could be detected even at a distance of 50 feet. Suppose there were many thousands of motor-cars running in the streets of a city, he would ask what the smell would be ?

The cost of a good motor-car, made as perfect as it could be, to carry from 4 to 6 persons was at least 400*l.* to 500*l.* A good reliable motor-omnibus to carry 10 or 12 persons cost 800*l.*, or even as much as 1000*l.* A tramcar to carry 50 or 60 people certainly cost no more in proportion to its capacity than other forms of vehicles. He believed, therefore, that the difference was in favour of tramcars relieving the traffic by the greater number of passengers they carried each time, instead of intensifying the congestion of street traffic; nor were the tramlines obstructive, as suggested by Mr. Beaumont. The great public service tramways rendered was sufficiently proved by all the lines at work, while motor-cars had still to prove it.

Mr. JOHN KNIGHT said that if there was one thing which the last speaker had done it had been to make it perfectly clear that, should the present tramways be abolished and motor-cars adopted in their stead, the roads of London would have to be three or four times their size. But he understood that the object of the discussion was to point out, if possible, what improvement could be made in the construction of roads, or what could be done to relieve the at present congested condition of main thoroughfares, not only in London but in every other city throughout the country. He thought that the *modus operandi* which would be indicated would be a system either of overhead roads or of underground roads, or the widening of the roads where it could be effected.

As Mr. Beaumont had said, the cost of the acquisition of property in London was so enormous that it would almost bring about a national debt to make a new street, such as was now being made in the widening of Newgate Street. He was old enough to remember Newgate Street being widened on the last occasion. It was only in the year 1858. A property which was sold by the Corporation at that time for as little as 2800*l.* they had now to acquire at a cost of 7500*l.* for the freehold, and they had to pay an enormous sum of about 20,000*l.* or 25,000*l.* for the trade which was occupying the property. But, notwithstanding the cost of property, the streets of London would have to be widened. Shoreditch and Bishopsgate Street wanted widening at the present moment. Cornhill had been in the process of being widened ever since he could remember. The Strand and Ludgate Hill were also being widened. The process had been going on for years, and it must continue to go on. Widening was, he believed, the proper method of improving the traffic.

Another method was the construction of such roads as the Embankment. The Victoria Embankment must be an enormous relief to such a thoroughfare as the Strand. Widening was a direction by which the traffic must gain relief. Underground railways might be very convenient, but they ruined the streets under which they passed, and he knew of shopkeepers who had been absolutely ruined by them.

Mr. A. MORESBY WHITE said that he had been very much interested in Mr. Knight's remarks, because he somewhat disagreed with him. The idea of the skeleton map which had been distributed in the meeting was magnificent; but he did not know whether those who had prepared it had considered the financial view of the question. Upon whom was the cost to fall? Would any Chancellor of the Exchequer who valued his position or the position of his party have the temerity to bring in such a scheme? For example, take the new arterial road which was to run from the north-east of London to Snaresbrook. Had the proposers considered where they were going to get the money from to carry out the work? Anyone who knew anything about the acquisition of property and the working out of bye-laws for the making of new streets knew that the great difficulty was the enormous expense of acquiring old frontages and throwing them into the highway. Such a scheme involved not only a drawing upon the present time but upon futurity. He thought that those who would have their rateable value mortgaged for experiments of that kind would have something to say. The scheme of the map was a grand one, but how was it going to be worked? Let them look, for instance, at the road which was to run south-west from Southwark. Another example on the map was marked "New roads through country districts," one of which was from Hornsey to Hampstead. But was that a country district? Then there was a road from Hammersmith to Wandsworth. Was that a country district? It might be said that the cost would be got to a certain extent by betterment, and there were one or two other minor issues. But the real point was whether they would get any person in the House of Commons, or anywhere else, to advocate the enormous expenditure which must come, not upon rates, but upon taxation, for the construction of arterial roads of this kind round the metropolis. He ventured to think that they were not so necessary as all that.

He would suggest as a topic for discussion that there was a distinction between roads in large cities and roads in the country. The question of road locomotion, to which Mr.

Beaumont had referred, was totally different in the country compared with what it was in a great city. There were not more than half-a-dozen great cities in the whole of the Empire which could be compared to London. Liverpool, Manchester and Glasgow were the only three towns which could parallel London. London stood upon a distinct basis.

He thought that the question of the regulation of traffic had not been sufficiently dealt with. The reason why the present streets could not take the traffic was because the traffic was not regulated. He would eliminate a certain amount of the omnibus traffic, and confine the heavy goods traffic to certain regulated hours of the day, and he would have goods for delivery in main thoroughfares taken to the back doors instead of to the front. A great deal of the slow-going traffic could be eliminated, and the streets could be kept for fast vehicular traffic. Heavy vehicles with goods had no right to monopolise a space like Ludgate Hill between 10 and 6 in the daytime. The County Council had been praised for making the new street from Russell Square to the Strand, but he did not think that such a street had anything to do with the problem at all. It was simply making a broad thoroughfare between one *cul de sac* to another *cul de sac*. The question was how people were to be got in and out of London. How people were to be got from Russell Square down to the Embankment was only a crumb in the loaf. What was wanted was not so much new streets, made at great expense, but the regulation of traffic.

It was idle to suggest that there was no sort of supervision at the present time for what Mr. Beaumont had called the network of suburban streets. There was very strong supervision for them, and the bye-laws which regulated suburban streets were approved by the Local Government Board. But he thought the basis of the approval was altogether wrong. The regulations ought to provide that, when there was going to be a new arterial street, it must be of a certain width—not 50 feet but 80. Good minor streets were absolutely essential. In the question of road locomotion, the serious point to be considered was not so much the connection between two points like Holborn and the Strand, or the north and the south of London, but the connection between the country and London. Mr. Beaumont might, perhaps, have touched more upon that particular topic. The road question outside the metropolis was a question of how people could get into the metropolis and how they could get out of it; and he did not believe that either a deep level railway or a shallow tramway would finally solve that question.

Mr. C. Rous-Marten said that he had taken special interest in the subject under discussion, not merely because he had studied the matter for many years, but also because he happened at one time to be staying in the city which he believed was the earliest in the British Empire to adopt mechanical traction in the streets—the city of Wellington in New Zealand. In that case the steam tramway was adopted. The plan was that of separate locomotives drawing cars. There was no doubt that the improvement in point of speed to which Mr. Beaumont had referred was quickly gained. He was quite aware that motor-cars never on any occasion exceeded the limits allowed by law, but the tramway drivers in Wellington, whom he had often timed, went at a speed of from 22 to 25 miles an hour. That was very satisfactory as regarded speed, but the speed had its drawbacks. On one occasion, while the tramcar was travelling at 25 miles an hour, a horse and cart happened to come across the street; the results were carried away in wheelbarrows. Two or three people were killed by New Zealand steam trams, and that annoyed the public. After a year or two of trial the steam locomotives were ignominiously relegated to a back yard; horses were substituted, and they had continued to be used ever since. But he believed that electric traction was about to be tried.

He had been struck with the extreme backwardness of London in point of locomotion as compared with almost any other large place that one could go to, or even with small places in England, or villages on the Continent. It seemed amazing that at this time of day the people of London should content themselves with the harmless necessary horse. Petroleum engines had been referred to, and they had been objected to on account of the smell which the petroleum produced. But the refuse of the horse was not always reminiscent of otto of roses. He had found London streets which held quite as much smell as he could stand.

He could hardly realise the idea of the Wellington cars travelling at 25 miles an hour along Fleet Street. London had its limitations. And yet, when we compared the getting about London with the means of transit in such a place as Norwich or Newcastle, we must, he thought, feel ashamed of the greatest city in the world. The difficulty, of course, was to find a remedy. Those remedies which had been suggested seemed to him to involve serious drawbacks and enormous expense. The plan to which he was about to accord his preference, no doubt suffered under the difficulty of being a very costly one, and yet he believed that it would prove inevitable. That was the shallow subway. As an engineer, he was perfectly aware of the enormous difficulty of constructing such subways, and the heavy expense which they would involve. But he thought that when all the points were taken into consideration, it would be seen that, on the whole, the shallow subway had immense advantages. He needed not to go into the question of tube or underground railways. They were all aware of them and of their drawbacks, but, from what he had seen of the working of the partial development of the shallow subway system in Paris, it appeared to him that it had a great deal of promise for the future. No doubt there would be vast expense involved in dealing with the various underground constructions, such as sewers, water mains, gas pipes, and electric wires. But then every plan that could be suggested was subject to drawbacks, and it seemed to him that, supposing a serious beginning was made at once in one of the main arterial thoroughfares in London, and supposing the heavier traffic was carried immediately beneath the surface, instead of above it, the streets would be left very largely free for pedestrians and for ordinary vehicles. Further, the system would get rid of the terrible nuisance, which had been experienced so greatly for the last few years, of the streets being continually broken up to repair telegraph wires or gas pipes or something of that sort. He was aware that the system was full of difficulties and complications, but he thought that, on the whole, it offered great promise and possibility of ultimate success.

Mr. MORESBY WHITE said that the main question was the getting in and out of London. He could hardly agree with him, for he thought that anybody who had even to go across London from east to west, and much more from north to south, would realise how great a disadvantage London was at, compared with Melbourne with its swift cable-trams along every street, taking people everywhere. He believed that if the plan of the shallow subway was seriously taken in hand and tried, with the aid, possibly, of motor-cars or tramcars beneath the surface, it would really meet what was at present the greatest difficulty in the management of London.

Mr. W. REES JEFFREYS said that he thought that Mr. Beaumont had shown conclusively that one of the main causes of traffic congestion in London was the inadequacy of the existing main roads. There were two methods by which that inadequacy might be removed. The first was to increase the width of the existing roads, and the second was to build alternative, or new, arterial thoroughfares.

The first plan, that of increasing the width of the roads, had been tried at an enormous cost. He believed that at the present moment the capital commitments of the London County Council and of the borough councils in London, in respect of road widenings now in hand or about to be commenced, exceeded 12 millions of money. Notwithstanding the expenditure of these enormous sums, we were making very little progress towards the solution of the difficulty. As Mr. Knight had pointed out, we removed the frontage line a little further back, and then after a few years it had to be removed back still further at even greater cost. That method seemed most unsatisfactory, especially when it was found that at the present time the outlying districts of London were being built over, and no proper provision made for new arterial thoroughfares. Under the building bye-laws in operation in the suburban areas outside the county, the frontage line was allowed to be brought so near to the centre of the roads that one would imagine that it was desired to make future road widenings as difficult and as expensive as possible. That was a state of affairs which reflected considerably upon the collective intelligence of Londoners. Notwithstanding the experience which had been gained in the inner area, the same mistakes were being repeated in the outside areas.

The suggestion with which to some extent his name had been associated, was that of building new arterial thoroughfares, and he would deal at once with the question of cost which had been raised by Mr. Moresby White. He had shown the wastefulness of the present system. We spent money in widening, but we did not create any fresh frontage values by the widening. The suggestion which he made was that new frontage values should be created. For instance, if a new east to west traffic artery was made through land that had not been formerly traversed by an arterial thoroughfare, the value of the land was greatly increased. It was obvious that if, by driving a new arterial thoroughfare through land, which, though only 10 miles from the Bank, had little more than an agricultural value in consequence of its being two hours distant from the city in point of time, that land could be brought within forty minutes of the city in point of time, a building value would at once be given to it. If some portion of the enormously increased value which was given to the land could be devoted to the building of the road, it would go some distance towards solving the question of cost. The question of cost lay at the bottom of the problem. He hoped to have an opportunity, sooner or later, of explaining fully before the Royal Commission on London Locomotion, the results of his investigations. The present plan of widening existing thoroughfares without creating new frontage values was a wasteful one. The creation of fresh frontage values would go some way towards the recoupment of the cost of driving new arterial roads.

It seemed to him that road building, so far from being an expensive and profitless enterprise, might be made a profitable one. That seemed a rather strong assertion, but he wanted to draw attention to one or two broad facts. In the first place he would point out, that during the last forty or fifty years no new arterial thoroughfares or new trunk roads had been built, either out of London or in any other large towns. When the turnpike system was abolished, trunk road building ceased, and, although streets had multiplied rapidly since that date, they had not been constructed so as to take the through traffic. They had only served to feed the traffic on the existing roads. During the turnpike era, trunk road building was a profitable form of investment for private capital, and new trunk roads were built. With the abolition of the turnpike system, the inducement to provide capital for making new trunk roads was removed.

At the present time it was to the interest of groups of men to put their money into railways, tubes and trams, and such undertakings were constructed; but it was to nobody's interest to put money into the building of trunk roads, however advantageous those roads might be. The problem which he had been trying to think out was how to make trunk road construction a profitable form of investment for private capital, without once more going back to the toll system. He quite recognised that the Chancellor of the Exchequer was very unlikely to find very large sums for trunk roads, though he might be willing to give grants in aid, as he did for light railways in certain districts. He further recognised that municipalities were unlikely to find the money. There was an outcry against the increase of local debt, and Parliament was likely to place a limit, if possible, upon local indebtedness. Therefore, there seemed little hope of building arterial roads by money drawn from the public purse. He would not say how far he had gone in the way of finding a solution to this question, but he believed that the solution of the traffic problem depended on making trunk road building a profitable enterprise.

Various other solutions had been suggested, and he did not raise any objection to them. By all means let them be tried. The problem was so great that there was room for all sorts of remedies.

He agreed with what Mr. Moresby White had said as to the need of further traffic regulations. He agreed to some extent with underground trams, but the lines of those trams would necessarily follow the existing lines of trunk roads, and they would not open up new districts for housing purposes. The driving of new arterial thoroughfares was a remedy which promised to meet many elements of the difficulty, and he believed that, besides being a remedy for the traffic difficulty in London, it would also solve the housing difficulty, and many other most acute social problems.

Mr. B. DENHAM HEALEY said that if the ordinary roads were always available for traffic that would be one point gained, but there was always something to block them. It should be a regulation that when pipes, telephone conduits, and other things of the sort, had to be put in repair, the repairs should be done at night time during certain hours; and the police ought to be allowed to have further powers to regulate heavy traffic as compared with light traffic. What was the Embankment for, if it was not to have some of the traffic turned on to it? The Strand and Fleet Street were often blocked from morning to night, and the Embankment was almost neglected. Again, if the surfaces of the roads were kept in repair, the traffic would be able to be conducted more quickly. He must admit that, on the north side of the river, the roads were generally in excellent repair, and those of Islington in particular, but on the south side that was not always the case, for many of the roads were very badly kept.

Underground conduits were not a new idea. He remembered them being discussed twenty years ago when he was in Liverpool. Mr. Bazalgette had the idea, when he built those magnificent underground areas in which some of the pipes were then laid. But the idea needed to be carried out. One of our Past-President's, Mr. Mason's, cherished ideas was to place all pipes underground. But as to getting people to go underground to use shallow tramway conduits, he did not believe it could be done. But the New York method of overhead lines might be carried out.

Some of the large manufacturing works might be moved entirely out of the City. Several large firms had already removed their principal establishments to the country. He dealt with this subject some two years ago, when the present Prime Minister was labouring under the idea that motor-cars would relieve traffic. But if the great works were removed out of London, the congestion of the traffic would be got rid of. And, not only so, but the manufacturers would get labour at a lower cost. They would get land almost given to them, and the workmen could get houses at much lower rents than they had to pay in London. Production would be carried out at a lower rate, and profits would be increased. He had had experience of that himself. Some twenty years ago he removed works out of Liverpool to a place near Preston. Everything was moved and set going again within about twelve months; and at the end of three years there was not a penny owing. The whole thing had paid for itself. The land was almost given away, and there was a reduction of wages.

The subject of the discussion was one in which he had been particularly interested. He had no original idea as to how he would get rid of the traffic, but the question of the removal of works out of London was an idea of his own. A scheme had been mooted for building main roads for the special use of motors alone. If such roads were built they would pay out of the increased value which would naturally arise from the land being devoted to building purposes, and one part of the problem would be solved in that direction. The general use of such roads would enable agricultural produce to be brought into cities at a lower cost and in a fresher condition than at present. Vegetable produce of all kinds could be brought direct to London within twenty-four hours by motor-cars, and at a less cost than at present. He believed that the general use of motor-cars would be brought about later on.

Mr. **Arthur Rigg** said that he would take the meeting to the other side of the world for a few minutes, as he had brought a photograph (which was exhibited), showing the birth of an exceedingly interesting town—Silverton, in the Rocky Mountains. What was done there was first to make wide roads in every direction on the grass of the prairie, and not as we did—build houses first and make roads afterwards. It would be very easy to say a great deal in contrasting that method of working, most favourably with that method by which the County Council allowed the growing suburbs of the metropolis to be arranged. There were no broad thoroughfares giving a general direction, say like Oxford Street, which was formerly a country high road, but there was a succession of mean streets difficult to be found, especially by strangers. There was scarcely a town in the United States where a stranger could not easily find his way about, and if we were obliged to submit to the arrangements made by our forefathers for older localities under different conditions from the present ones, there was no reason why the new suburbs should not be laid out with due regard to common sense.

Mr. **H. G. Burford** said that the question under consideration was one to which he had given a small amount of study. He thought that previous speakers had largely neglected the main feature of the question, and that was the slowness of the present movement of the traffic. The streets were congested with traffic which was moving at from 4 to 6 miles an hour, when it might be moving at the rate of 8 or 9 miles. Mr. Conradi mentioned a motor-omnibus running between Cricklewood and Oxford Circus. As a matter of fact such vehicles might move at a speed of from 8 to 9½ miles an hour on an average. The average of the 'buses of the London Road Car Company was 6 miles an hour. An increase of 3 miles an hour in the speed of the traffic would clear the streets to a very large extent. Motor vehicles which were now being used for carrying passengers took 36 people. That was more than the 8 or 12 which had been referred to. If vehicles carrying 36 people could be carried through the streets at an average speed of from 8 to 9 miles, the present choking and congestion of the city traffic would be considerably remedied.

Mr. BEAUMONT, in replying on the discussion, said that Mr. Conradi had given statistics to show the tremendous number of people which tramways had carried in different places. He (Mr. Beaumont) might sum up what he had to say upon that point by stating that the railways had carried even more people than the tramways; but railways were not allowed to run through the streets, except at Newport in Monmouthshire, and in some places abroad, and in those latter places there was no congested traffic to be dealt with. In answer to Mr. Conradi's figures he would state, as a general proposition, that, when any one particular kind of traffic should require an iron way for its accommodation, the special functions of a railway were called for. No streets or roads in towns could be converted into unfenced open railways without detriment to everything else. A tramway was a railway, whatever it might be called; and when it was really required the condition of railway traffic had arrived, and the railway should be put in a place by itself. If two lines of rails might be laid for a tramway, there was no reason why, ultimately, there should not be four. In crowded streets tramways simply became badly managed railway-sidings in which every conductor was an incompetent sort of railway manager with only one view to act upon. If tramways were to be laid in the future on roads common to other users, then the tramway companies or authorities, and the highway authorities, should together meet the expenses of constructing sufficiently wide roads to permit of both tramways and ordinary traffic. He admitted as readily as any one the value of tramways, but there were proper places for them, and crowded streets were not those places. Mr. Knight agreed with him that, if the traffic was worthy of its existence, it was worth while to make some expenditure now for its accommodation, rather than to wait until the expenditure must be even greater. Mr. Moresby White was frightened at the cost of widening, and asked where the money was to come from. He (the speaker) would ask why London, the richest city in the world, with the heaviest traffic in the world, should not be as able to find the money for the improvements as places like Paris had done. Mr. White had alluded to the fact that plans for new streets had to be submitted to the local authorities. But the present powers of the local authorities only applied to the width of the street and other minor matters, and the authorities could do nothing in the direction which was so much wanted.

Mr. White had also alluded to the alteration of the roads, and said that if what had been suggested was to be carried out, all the roads would have to be put into a good condition and maintained in that condition everywhere. Well, he (Mr. Beaumont) was sorry that that should be considered a hardship. It was a great pity that it was not more generally felt that the proper maintenance of a road was one of the best possible investments that the people of any country could take up. In the address which he delivered before the Society in 1898, he showed that we might expend 125 millions on roads at a return of 3 per cent. He was just as well satisfied of the truth of that now as he was in 1898, and, if that could be done, he did not see why Mr. White should feel sorry that that sum would have to be expended, and look upon it as a waste, although it was only for maintaining the roads in a better condition everywhere. It would be to the good of everybody that that should be done.

Mr. Denham Healey said that there were certain districts in which the roads were badly kept, and other speakers had referred to the bad state of the roads. No one knew better than the President that the better the road and the better its maintenance, the less it cost. The roads should be made as good as possible, and they should be maintained in that way which would cost the least, namely, the best.

Time did not permit him to dwell upon the general question of improving the means of getting the traffic through existing streets. If they had a channel of a given size and wanted to get a certain quantity of material through it, that material must go at a speed which was proportional to its quantity and the area of the channel. The traffic which they wanted to get through the streets of London was so great that, unless more channels were provided the velocity of the traffic must be increased. He did not care how it was done, whether by horses or by motor vehicles. But he contended that they could not do it by tramways with the present traffic, because the proportion of the requirements of the other traffic to the requirements of the tramcar traffic was so enormous. He therefore repeated that the question was one of the speed at which the traffic could go through streets of a given size.

He thanked the meeting very much for the way in which they had received the present innovation with regard to their proceedings, and allowed the discussion to be opened without a paper. He thought that this new departure would be considered anything but a failure.

April 6th, 1903.

J. PATTEN BARBER, PRESIDENT, IN THE CHAIR.

ROAD MAINTENANCE AND ADMINISTRATION.*

BY R. J. THOMAS.

MUCH has recently been said and written relative to the roads of this country, and divers suggestions made with the view of improving their condition and administration. The author desires to lay before the Society of Engineers some facts, figures, and opinions, gleaned from the daily routine of actual work during some fourteen years' experience in direct maintenance of main roads in Welsh and English counties, so that they may be compared with the numerous theories and recommendations propounded in press and pamphlet.

MAIN ROADS.

It is essential, as a preliminary to discussing roads in detail, to emphasise the fact—which several writers apparently are unaware of—that the term "main road" has a definite legal meaning, and that to use it indiscriminately adds, quite unnecessarily, to the confusion of the ordinary mind when considering the subject. It is either a disturnpiked road or a highway which a county council, in the exercise of its powers, has declared a main road; no other road, old or new, trunk or artery, should be so described.

Every main road is repaired and maintained at the cost of the county fund, whether the actual work is carried out by the county council direct, by rural district councils on the requisition of or by agreement with the county council, and at a cost agreed to, or, in the latter case, determined by arbitration of the Local Government Board, or by urban authorities who have claimed to retain in their own hands the management of those within their areas. In the case of rural district councils maintaining, a county council, if dissatisfied with the result achieved, can, if notice served upon the district council to improve any particular road is not complied with, do all that is necessary at the cost of the district council; and may, from that or any other cause, decline to renew the agreement, and assume direct management. Where urban councils maintain, a county council can withhold the whole or any portion of the amount due should the urban roads not have been maintained to its satisfaction. In both cases it is essential before payments are made that the county council shall be satisfied by the report of the county surveyor, or other person appointed for the purpose, that the roads have been properly maintained; so that county councils have real and practical control over all subordinate authorities entrusted with main road maintenance, and are not likely to sanction a variety of modes of working or degrees of efficiency.

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* The Bessemer Premium was awarded to the author for this paper.

It is therefore wrong to assume, as has recently been done, that the methods and systems of maintenance and efficiency aimed at in an administrative county must necessarily vary according to the number of rural and urban councils directly maintaining the main roads within their areas, and to assert that these authorities are responsible to no one for the methods they may chose to adopt in dealing with the 10,992 miles of main roads which were maintained by them, on behalf of county councils, at the close of the year ended March 1901.

MILEAGE.

There are sixty-two administrative county councils in England and Wales, excluding the County of London and county boroughs. The Isle of Wight having its own special clause in the 1888 Act (and no provisional order having been obtained), and West Suffolk having no main roads, there are thus sixty county councils responsible for the 26,978 miles of main roads existing in March 1901, an average of 450 miles each. This total is divided as follows:—

	Miles.
1. Rural main roads maintained directly by county councils .	15,582
2. Urban main roads maintained directly by county councils .	404
3. Rural main roads maintained by rural district councils and superintended and paid for by county councils . .	7,408
4. Urban main roads maintained by urban district councils under their powers (reasonable cost repayable by county councils if satisfactorily maintained)	3,584
Total . .	26,978

The second division is principally roads which were main roads prior to the districts through which they passed obtaining urban powers, and consequently beyond their power to claim to retain, also a few cases where urban councils failed to claim within the prescribed twelve months, or preferred leaving to their county councils. The Kent main roads are let to the lowest tender, whether district council or private contractor, and it is doubtful how they are allocated in the foregoing.

Cost.

For the year ended March 1901, the mileages, expenditure, and average cost per mile, exclusive of loans, were as follows:—

	Miles.	Cost. £	Per mile. £
Rural and urban main roads repaired directly by county councils . .	15,986	980,601	61
Rural main roads repaired by rural district councils for county councils .	7,408	423,899	57
	23,394	1,404,500	60
Urban main roads repaired by urban district councils and paid for by county councils	3,584	715,832	200
Gross total . .	26,978	2,120,332	78

The expenditure of each county council therefore averages 35,339*l.* annually on a length of 450 miles.

In 1889 the mileage of main roads repaired by highway boards, rural sanitary authorities and surveyors of highways, was 18,070, so that there appears to have been an increase of 8,908 miles.

County Council Control.

It is to these sixty county councils that the duty of maintaining this mileage of main roads has been entrusted by Parliament, and it is from their funds, raised by an even rate throughout each county, supplemented by Exchequer contributions, that the repayments to smaller authorities are made when satisfactory evidence of efficient maintenance has been forthcoming.

Systems Adopted.

The systems adopted for maintaining rural main roads (and those in "unclaimed" urban districts already described) are as follows:—thirty-eight county councils maintain by direct management; eighteen county councils entrust the work to rural district councils by agreement or requisition (this includes the county of Kent which lets by tender to district councils or contractors); four county councils use both methods in about equal proportions.

ADVANTAGES OF DIRECT CONTROL.

Dividing the third description equally, we have exactly two-thirds of the county councils adopting direct maintenance, and this must surely be the system most conducive to efficient and economical administration. To enumerate a few of the advantages:—By direct control it is easier, in purchasing large quantities of materials, tools, etc., to obtain tenders at the lowest market cash prices, to make it worth while for granite merchants to break and screen their stone to comply with the specification of any particular county; to purchase and find constant work for steam rollers and their necessary appliances; to effect extensive improvements or urgent works of magnitude such as the removal of exceptional snow-drifts, landslips, etc. in one part of the county without appreciably increasing the gross expenditure over such a large mileage of roads; to systematise and compare the daily work of the various rollers by means of time sheets indicating quantity of material consolidated, time occupied, fuel and oil consumed, etc.; to effect substantial improvements, road widenings, reductions in gradients, etc. expeditiously and economically by concentration of labour, plant and supervision; to keep detailed records and analyses of materials used, tools issued, rolling and carting done, and labour employed, on each section of road year by year, and so be enabled to detect and rectify any unnecessary excess or leakage; to know that all material paid for has actually been used on main roads and nowhere else; to have the undivided interest and attention of officials; to effect uniformity in rules and instructions throughout the county for the guidance of foremen, lengthmen, and extra labourers; to employ competent, able-bodied men as permanent lengthmen, in charge of sections of road sufficiently long to keep them in regular employment throughout the year, and not dependent upon others for summer work, and to encourage personal interest in their sections by a regular system of minor promotions; to treat every application for improvements on a broad basis, free from partiality and local feeling or prejudice; to modify the extent or character of new work or ordinary repairs, should the progress of the work or the season render necessary or expedient; and in general, the obvious advantages obtainable when wholesale and direct methods replace retail and sub-letting.

As frequent charges of extravagance and increased expenditure have been made against the present road system, of which main roads form a very large proportion, it may be of interest to state that the average cost per mile of the rural main roads under direct management in Buckinghamshire was 61*l.* during the first five years of county council control, whereas for the previous three years, under parish control, it averaged 65*l.* During the past eight years (when the mileage was increased to 440), the average was 53*l.*, and this figure includes the purchase of six steam rollers and appliances, and the substitution of granite for flints on the majority of roads. This is put forward, not as an exception, but as an instance of what the majority of county councils can look back to as the result of their labours during the past thirteen or fourteen years.

Materials, Quality, Size, and Testing.

Of recent years there has undoubtedly been a very marked tendency to use harder and more durable stone for road maintenance. Evidence of this is abundantly forthcoming in the rapid growth of the stone quarrying industry throughout the length and breadth of the land, especially in such stone-producing localities as Leicestershire, Shropshire, Cornwall, Warwickshire and various others, not to mention importations from Guernsey, Belgium, France and Norway.

Ordinary granite is but an indifferent material for broken roadstone, but the development in stone quarrying has resulted in the adaptation of the term "granite" to trade purposes, and at the present time the word is used by engineers to denote hard quarried stone, whether trap, basalt, syenite, and even mountain limestone, to distinguish them from gravel, local soft stone, or field flints. Flints, when hand-picked from fields, though providing material suitable for light country roads, pulverise under heavy or continuous traffic, and in consequence of the non-cohesive properties of their silicious detritus, soon work loose in dry weather; for the same reason they give far more mud and dust than is desirable.

Gravel, unless unusually hard and wear-resisting, cannot be recommended for important roads unless, as is sometimes the case in rural districts, excessive distance from a station makes the price of granite, plus carting, prohibitive. Slag has been used to an increasing extent of late years, especially for light roads, in the neighbourhood of ironworks. The recently patented invention of an engineer of great experience in road maintenance, whereby hot slag is mixed with tar by machinery and impregnated with its oil, is claimed to produce a surface practically impervious to moisture (the bane of road maintenance) and free from dust and mud. The author hopes to utilise this material when obtainable, and ascertain its capabilities under varying conditions of traffic and situation.

It is now generally admitted that metalling should not in any case exceed a gauge of 2½ inches, i.e. must pass through a ring of that diameter, and a very large number of county surveyors, the author included, have satisfied themselves that, for country main roads, nothing exceeding 1¾-inch or 2-inch gauge should be used. This is qualified by the important reservation that only stone which breaks cubical and is sufficiently tough to resist excessive bruising in the crushers now in almost universal use, should be depended upon in the smaller size; and it will be found that this qualification is generally required by county surveyors.

The various methods in use for testing granite intended for metalling appear to the author to be of varying practical utility. The ingenious contrivance for ascertaining the proportion of small particles which a given quantity of stone will produce by attrition when spun round in a revolving cylinder, although establishing the superiority of a particular stone under that violent operation—serviceable perhaps if traffic should ever assume "looping the loop" methods of progression—affords but little evidence as to its probable behaviour under the varying conditions of weather, traffic, subsoil drainage, and the almost imperceptible oscillation in the body of a road. Neither is the crushing strain which an accurately cut and highly polished cube will withstand any criterion of its wear-resisting properties, unless the traffic it is supposed to receive consists of stupendous weights concentrated gradually upon each single stone. A carefully cut and polished field flint will bear a greater crushing strain than almost any stone, but its qualities as a road material are quite moderate. In the author's experience the most reliable granite is that which, when machine broken, contains the largest proportion of cubical, and the smallest of bruised, cracked and chipped stone when passed through a powerful crusher, has at least 75 per cent. of its weight over 1 inch in size (if of 1¾-inch gauge), absorbs the least quantity of water, and, most important of all, lasts longest under traffic.

Various ideas have been expressed relative to the methods adopted for spreading and packing granite on the old surface to be coated. One writer some few years ago seriously advocated the ramming of each individual stone into the surface of road by manual labour, and even when the annual cost—estimated at something approaching the national debt—was brought to his notice, wavered not in his opinion. A suggestion was recently made for effecting the spreading of metalling and ensuring each stone lying on its broadest face, by either laying each one by hand or constructing a machine to do so; and another writer, emphasising this hand-laying suggestion, facetiously remarked, that to obtain the best results either this method would have to be adopted, or a series of earthquakes invoked for the purpose. As the labour per ton for this wholesale mosaic work would cost at least twenty times that of the present system of spreading, the author need hardly point out the impracticability of the proposition.

Machine broken 1¾ inch gauge granite, if not passed too quickly through the revolving screens, will be found to contain not less than 75 to 80 per cent. of stone exceeding ⅞-inch gauge, and the remainder equally divided between sizes below ⅞ inch, ⅝ inch and ⅜ inch. With these proportions there is but little difficulty in a competent roadman spreading, shovelling, turning, and packing his metalling for a completed coating one stone thick, so that the larger stones find their bases and are packed closely together ready for effectual incorporation with the old surface by steam roller. No joggling machine could possibly regulate the depth of the metalling according to the inequalities of old surface, neither could it produce other than lateral oscillation.

WEAR.

During the past five years the author has subjected granite to a test of wear, with the following results. When coating in granite and rolling a typical 20-foot country main road with a gradient of 1 in 50, a portion 50 yards long was placed under observation, the measurements of depth being taken from the underside of a straight-edge with 12-inch pendent feet at each end laid across road, and the feet resting on steel pegs sunk in turf level with side gutters. The road had an excellent foundation of large stones, and an average depth of 5½ inches of metalling composed for the greater part of hard pebbly flints, there being ½ inch of granite 9 feet wide along the centre of the road. For coating, 1¾ inch machine-broken granite was used, 18 cubic yards, or 19 tons 14 cwt., being required for the area referred to; no scarifying was done. After thorough dry rolling it was well watered and had 28 cubic feet of clean sharp scrapings, equal to 5·75 per cent. of the granite used, added as binding. This produced a solid compact surface, which remained so, as the sample on the table, cut out of the centre of the road five years later, demonstrates.

In order to ascertain the exact proportions of sizes of stone before and after rolling, a portion of this new coating—easily distinguished—was removed, screened, washed, and compared with unused stone of the same quality, with the following result:—

	Before rolling. Per cent.	After rolling. Per cent.
Exceeding $\frac{7}{8}$ inch gauge	87·3	66·6
„ $\frac{5}{8}$ „	6·8	8·0
„ $\frac{3}{8}$ „	3·5	5·4
„ $\frac{1}{30}$ „	2·4	8·0
Under $\frac{1}{30}$ „	nil	12·0

The 12·0 per cent. under $\frac{1}{30}$ inch included the 5·75 per cent. of clean scrapings used as binding.

Sections across road 12 inches wide and excavated to the foundation immediately after rolling, and five years later, gave the following proportions:—

	After rolling.	5 years later.
Over $\frac{7}{8}$ inch	43·8	34·7
„ $\frac{5}{8}$ „	11·4	11·5
„ $\frac{3}{8}$ „	11·4	12·6
„ $\frac{1}{30}$ „	18·6	21·7
Under $\frac{1}{30}$ „ (washed)	14·8	19·5

During the five years 358 cubic feet of sweepings and scrapings were removed off the road, and frequent tests showed that unless containing more than 28 per cent. of water the bulk was not affected. Careful readings taken from straight-edge (on another pair of pegs) immediately after rolling, and a repetition five years later on same pegs revealed the following wear:—

	Width. ft.	in.	in.
Average over the centre	7	0	1·547
„ „ near side (ascending)	6	6	·685
„ „ off side „	6	6	·625
„ „ entire	20	0	1·003

The traffic taken for a week amounted to 1916 "collars" and was exclusive of saddle horses, cattle, traction engines, etc. This is equal to about 100,000 per annum, or half a million during the five years covered by these tests.

It would thus appear that 300,000 collars traversed the central portion of road and wore it away 1½ inches in five years, and that 100,000 collars used each of the sides and wore them down rather more than ½ an inch during that time. The average wear per 100,000 collars on a good granite road with sound foundation was therefore ½ inch. For the central portion of road it is desirable to estimate for three-fifths of the whole traffic.

In considering the question of how far the wear of macadam roads is divided between wheels, hoofs and atmospheric conditions, it has too readily been assumed that what obtained in the time of Macadam and Telford is necessarily the same at the present time.

Since a writer re-asserted this theory, and adduced as an instance where the wear due to horses' hoofs was palpably in excess of that caused by traffic, a Buckinghamshire main road maintained by the author, he has given particular attention to this subject, and has no hesitation in stating that neither on this nor any other road under his care, steep hills excepted, can he agree that anything confirmatory of this statement is to be seen. Even on hills it is not easy to determine the wear due to the relative causes, as, although the centre may be loose, it must be borne in mind that a horse uses his intelligence—there are few imbeciles amongst the lower animals—and reduces his labour by ascending in zigzag fashion, and so distributes the wear for which his hoofs are responsible.

Macadam wrote in days when women and children were recommended for use as stone-breakers, when roads were so rough and uneven that two-horsed carts were necessary for conveying a ton load, when steam rollers were unknown, and winter travelling meant arduous ploughing through seas of rolling stone. In the present day things have surely changed, the improvement in road surfaces has doubled the weight which a horse can draw, and necessarily altered the proportionate wear due to the two causes. By steam rolling solid impervious surfaces are now produced in the course of a few hours, which a in the old days would have required two or three months of vehicular consolidation to effect; so that the wear due to the intrusion of water among the oscillating stones in the body of road must necessarily be much diminished. It would be interesting to ascertain from a firm of country carriers the proportionate cost of shoeing and tyres twenty years ago and at the present day.

Steam Rolling.

The consolidation of road metalling by steam rollers has become so general on main roads and district highways throughout the country, that to discuss its credentials is unnecessary; but the author has satisfied himself that a 10-ton roller having driving wheels 16 inches wide and of large diameter, and front wheels 22 inches, distributes its weight to such an extent, as to make the pressure per square inch insufficient to consolidate effectually a coating more than one stone thick at a single operation, and that to attempt to roll in a bed 6 or 8 inches thick not only necessitates the use of unreasonable quantities of binding, but also reduces the effective pressure of roller very considerably, as it is self-evident that the greater the depth of a coating of stone the less the pressure on the old surface with which the new material has to be amalgamated. If spread for a finished thickness of one stone, well raked over and packed into position, rolled dry until the entire surface has been compressed evenly and does not yield appreciably under the pressure of driving-wheels, watered copiously, and rolled until liquid mud from the old surface exudes and can be swept into the surface interstices until they can take no more, a little clean sharp binding of road grit, not exceeding 5 or at most 10 per cent., being added where the foundation is too hard to afford this, there should not be much to complain of in its finished state.

There is a tendency in rolling to use too much binding material, foreign and local, it being probably overlooked that, however carefully screened the granite may be, there is always a certain proportion of smaller stone in every consignment, varying from 10 to 20 per cent.; that ample watering and rolling will produce a certain quantity of binding material from the old surface, and, what is most important, that during dry rolling and the resultant pressing and squeezing together of the stones as they find their natural positions, there is a considerable quantity of fine material produced from the stone itself, than which nothing better could be obtained for the purpose of binding. As already instanced by the author, stone which before rolling included 87·3 per cent. exceeding $\frac{7}{8}$-inch gauge, only contained 66·6 immediately after rolling; the difference going to swell the smaller sizes and providing 6 per cent. of fine dust for binding. This agglomeration will make a firm, solid, smooth surface yielding a minimum of mud and dust.

It was with considerable surprise that the author heard an engineer, eminent in other branches of the profession, express the opinion at a meeting considering a paper on roads, that steam rollers were not satisfactory because their driving-wheels always left indentations in the finished work! To those accustomed to the use of these machines it is obvious that the driving-wheels almost entirely complete and finish off all rolling, the front wheels doing little more than "keeping their ends up" and steering, and that the ordinary driver knows that until his road has been consolidated by the driving-wheels so that they make no impression upon its surface his work is not satisfactorily completed, and requires more rolling if he wishes to continue in the same employ.

SCARIFYING.

The introduction of machine scarifiers attached to or drawn by locomotives or steam rollers has done away with hand picking on roads where traffic is exceptionally heavy. On country main roads where the depth of metalling is not sufficient to allow of the removal of 3 or 4 inches at a time hand scarifying is still adopted, but it is questionable whether more is necessary than the removal of projections and the careful reshaping of road prior to the spreading of fresh coatings. The author makes it a rule to remove all scarified material for screening and future use rather than mix it with new stone, as the small detritus or mud which it contains is an unknown quantity, and, as already described, the proportion of this essential ingredient in a good road requires accurate apportionment.

When steam rollers of the present type were first introduced the utility of spikes bolted through the tyres of driving-wheels for scarifying purposes was much applauded, but, as practical tests soon demonstrated, the idea was abandoned years ago, as the work done was ineffectual and the strain upon the roller enormous. Apart from the great strain to which the working parts of a roller are subjected by the heavy impact of a scarifier —and the author strongly recommends all surveyors interested in the upkeep of their rollers to borrow a guileless neighbouring surveyor's, or hire, when scarifying has to be done—the objection to machine scarifiers attached to rollers is that they must "lift" the road to depths corresponding with the inequalities of that portion of road surface traversed by the wheels of rollers carrying them, and therefore do not produce what is required, i.e. an even, correct, and waveless surface upon which the new material has to go. If a roller travelled on tram-lines or other true surfaces, the scarifier would necessarily reproduce that surface.

CLEANSING AND WATERING.

Traffic produces dust or mud by disintegration of road surface proportionate to the quality of the materials of which it is composed, and the quantity of fine stone and dust which it contains. As moisture is essentially a road destroyer, and dust after rain becomes mud, it is necessary to remove this before or when it assumes the properties of a wet blanket as expeditiously as possible. Of recent years it has been the custom in most counties to utilise sweeping-machines before dust is converted into heavier and less manageable mud, and the principle is undoubtedly sound.

Surface watering during the summer months undoubtedly prevents the loosening of macadam, and the author has, after close observation, satisfied himself of the correctness of the late Mr. Santo Crimp's figures relative to the minimum rainfall necessary per day in order to keep a granite road sufficiently moist to prevent disturbance, i.e. nothing under ·04 inch. Taking the average number of days per annum during which the rainfall does not reach that quantity at 120 in the home counties, it follows that a granite road should receive 4·8 inches per annum for road maintenance, purely and simply, this being equivalent to two light or one heavy watering per day for 120 days.

If agreed to so far by all classes of road users, there are divergent opinions beyond. The cyclist complains of excessively soaked roads, side-slips and mud baths; the motorist approves of any watering necessary for laying the dust fiend so rampantly evident when velocity (not within official limits) is indulged in; and the shopkeeper, whose stock-in-trade suffers materially from dust, reasonably calls for additional watering to protect his goods—and pays for it.

The unfortunate selection of a newly stoned and rolled length of road running north and south, and closely hemmed in on both sides by thick trees, for experimenting upon with a copious dressing of oil, with the view of ascertaining its dust-laying capabilities, precludes any reference to the result. If another attempt is made on a suitable length composed of at least partly solidified surface, and open to wind and sun, more justice will be done to the idea, and some reliable data obtained.

LABOUR.

In effective road maintenance the most important essential is good intelligent labour, and, taking the present condition of the labour market into consideration, the author confidently asserts that the class of men employed as permanent lengthmen is equal to any and superior to most labour employed in any other work. The strictures passed by writers in the press on this class of men are, in the vast majority of cases, undeserved and incorrect.

Reference to the statements made in a pamphlet recently issued by the Roads Improvement Association on this subject cannot be avoided. In stating that country roadmen are recruited from the aged, incapable and unemployed, the author reproduces extracts from reports on main road labour by two county surveyors, ignorant of the fact that neither of these officials has the direct management of a mile of main road, and therefore employs no labour. Further, he adds that the state of labour in the country is similar to that in London, and, in confirmation of this assertion, proceeds to publish a speech delivered by Mr. J. Patten Barber, your President, at Leicester, but omitting a portion which ran as follows:—" Mr. Hooley is irritated by Mr. Beaumont's criticism of roads, but is not irritated by the men he (Mr. Hooley) employs on the roads in Nottinghamshire. I am unfortunately irritated by my men in London, and I am bound to say I quite agree with Mr. Beaumont that in very many cases we are unable to get men who can repair the roads with the same skill and intelligence that the old roadmen in the country exercise to the present day. I have, over and over again, when passing over a country road, and seeing the skilful way in which the men repair a road and trim up the bad places, wished that I could have such intelligent men to repair the roads in my district in London."

It is to be hoped that this method of making mutilated quotations will not become general in discussing this or any other important topic; it leaves a strong impression of unfairness.

What can be said of the suggested compulsory employment of tramps and casual loafers on roads, and the infliction of prisoners convicted of lesser misdemeanours upon quarry owners, whose property, it is recommended, should be turned into labour camps? Imagine the class of work done, the language permeating the atmosphere, the sanguinary encounters, the chaos!

The large majority of the permanent labourers in charge of sections of road in Buckinghamshire and other counties have been constantly employed upon them for 13 or 14 years, and take evident pride in their work; many have sons so employed, ready to follow in their footsteps when age and infirmities—too often due to the exposure inseparable from constant outdoor occupation in all weathers—relegate the worn-out servant of the ratepayer to the pittance of out-relief or the tender mercies of the dreaded poorhouse.

SUPERVISION.

The general system of supervision adopted by county councils maintaining main roads is that of dividing the county into divisions or districts, sufficiently large to require the whole time of a divisional surveyor or district foreman accountable to the county surveyor for the condition of his roads, the effectual control of labour and cartage, the inspection and approval of all consignments of stone, and the direction of every detail of road maintenance. This system approximates very closely to the much advertised French system of cantonniers, foremen, and engineer, shorn, however, of the glamour attached to the blue jacket, copper-banded leather hat, and numbered alpenstock.

In Buckinghamshire each lengthman has to indicate the place and nature of his daily work on timesheets divided under headings descriptive of every class of work, and the district foremen have to send in weekly diaries stating the hour when they left home and returned, the name of each lengthman seen, the time, what he was engaged in, the position of steam-rollers, machine-sweepers, etc., and any special work requiring attention.

Hedges and Trees.

To those who use country main roads extensively it must be evident that rapid strides have been made of recent years in cutting lofty hedges and lopping trees; indeed, in some picturesque localities, more appears to have been done than was essential. Very considerable care and tact must be exercised by surveyors in carrying out the unpleasant duty of requiring tenants and owners to cut or lop, as each case must necessarily be decided on its merits, and the owner of a hedge on the south side of a road convinced that for the benefit of the road his hedge should be laid, although his opposite neighbour has an equally lofty one left undisturbed. Trees, if close to the minimum distance of 15 feet from centre of road, undoubtedly do more injury than an ordinary hedge, as in addition to keeping off wind and sun to a greater extent, their overhanging branches drop moisture on to the surface of the road.

District Highways.

The transferring of rural roads, other than main roads, from various highway boards, parish surveyors, etc., to rural district councils, under the 1894 Act, very materially reduced the number of road authorities, and necessarily made for far greater uniformity and system in methods of maintenance. The reduction in Buckinghamshire was exceptionally pronounced, 11 rural district councils replacing 236 parish surveyors. In 1901, there were 672 rural district councils in England and Wales, maintaining 95,269 miles of district roads at a cost of 1,869,581*l.*, representing 19*l.* 1*s.* per mile, and an average mileage of 142 per council. This notable step towards uniformity, system and amalgamation of innumerable small authorities deserves particular attention, as recent writers in the press appear to have ignored the fact that highway administration has not been at a standstill.

By section 11 (10) of the Local Government Act, 1888, county councils were given power "to contribute, if they thought fit, towards the costs of the maintenance, repair, enlargement and improvement of any highway or public footpath in the county, although the same was not a main road." This power has been utilised by many councils in varying degrees, Lancashire and Buckinghamshire extensively.

In addition to declaring 209 miles of new main roads, the Buckinghamshire Council decided in 1892, when parish surveyors were in authority, to contribute towards every other highway in the county, urban or rural, estimated at 1240 miles, a sum not exceeding the average expenditure of each parish for the three years ended March 1892 (subsequently made progressive by dropping one year and adding a later one annually), such figures being obtained from the statistical department of the Local Government Board; the payments being subject to the observance of general instructions issued as to the quality and size of materials, time and method of spreading, drainage, cutting of hedges and lopping of trees, prevention of encroachments, and other essentials to effective maintenance. In addition, general advice was proffered and assistance given in the purchase of granite and provision of steam rollers.

That these resolutions of the council and the instructions referred to were not contrary to the intentions of the author of the 1888 Act, is evidenced by a letter received in 1894 from the Right Hon. C. T. Ritchie, himself a resident in the county, in which he says, "I think the rules and instructions of the council with regard to highways are excellent, and quite in accord with the spirit of the Local Government Act."

During 1893–4 and 1894–5, when these highways were under the control of parish surveyors, very considerable activity was shown and increased attention paid to the work with the view of carrying out the instructions given, and securing a full grant. As a consequence the author had comparatively few instances to report where deductions in the grants had to be made, especially as the policy adopted was one of encouraging gradual and steady improvement of each road, having due regard to its previous condition.

When district councils took up their duties in 1895 still greater activity was shown, and the deductions in grants, due to non-compliance with the instructions, were further reduced. Improvements were contributed towards in excess of ordinary grants, and so were steam rollers: the latter are now employed by every district council in the county, without exception. This increased activity necessarily entailed additional expenditure. The average for the three years ended March 1892, was 18,832*l.*, the expenditure by parish surveyors during each of the next two years rose to 25,500*l.*, and, when district councils took control it continued rising gradually until it reached 36,204*l.* in 1901–2.

Great though this increase was, the improvement effected in the roads generally more than kept pace with it, and but little complaint has been made by those using and paying for them. For the nine years ended March 1902, the net expenditure by urban and rural district councils amounted to 258,744*l.*, towards which the county contributed 210,236*l.*, and in addition paid 9640*l.*, the one-half of 19,280*l.* spent in improvements; a gross expenditure of 278,024*l.*, and grants 200,596*l.*, and an average per annum of 30,891*l.*, and 22,288*l.* respectively, equal to county rates of 8*d.* and 5¾*d.* in the pound. This expenditure, though double that obtaining in 1892, is strangely similar to the 8·4*d.* which was the average throughout England and Wales in 1898–9 for rural district roads.

In making these grants the county had necessarily to levy a proportionately higher rate, and, as this was collected throughout the county, every ratepayer subscribed equally, whatever the character or mileage of roads in his particular parish or district. This result of the scheme produced considerable dissatisfaction in the case of an urban authority where the length of highways was exceptionally small—practically all the roads being main roads paid for by the county—and the rateable value comparatively high, it being claimed that under this arrangement such authority was deprived of the advantage its local circumstances gave it, and had to contribute towards outside roads a larger amount than it received back in grants towards its short length of district roads.

It was claimed by this urban authority and by an adjoining rural district council (which, however, was neither losing nor gaining under the scheme), that the 1894 Act, section 25 (3), qualified section 11 (10) of the 1888 Act, and made contributions by county councils "subject to any such conditions for the proper maintenance and repair of such highways as may be agreed on between the county council and the highway authority." The two councils referred to having expressed their dissent from the conditions, obtained counsel's opinion in support of their contention, and the county council, having also obtained an opinion guardedly favourable to the opposite view, decided to withdraw the scheme as there was considerable doubt as to the legality of continuing it without the unanimous concurrence of the district councils interested.

It will be interesting to observe the effects of the withdrawal of contributions upon the condition of district roads and the expenditure. The author, from personal knowledge of the district surveyors—with whom most cordial relations have existed—has strong faith that no retrograde steps will be recommended, and that, taken generally, the district councils will neither advocate nor countenance any such undesirable policy. Quite recently the county council has decided to consider all specific applications for contributions when received from urban and rural district councils under section 11 (10).

Metropolitan and Town Streets.

As one whose labours have been directed towards the maintenance and improvement of country main roads and those in smaller towns, the author will only broach the vitally important question of metropolitan streets, and leave its discussion to those engineers present who have had life-long experience in their maintenance.

It is obvious that in point of size and traffic the streets of London are incomparable with those of any other town, past or present, also that the eccentricities of climatic conditions are unequalled elsewhere. These streets, though nominally controlled by the various road authorities, are practically the property of the numerous bodies to whom Parliament has in its wisdom sold the public birthright by granting power to dig and delve therein at their convenience and leisure. It is only on rare occasions, when his principal streets are not in the hands of the closely barricaded and entrenched excavator, and the pavements are devoid of canvas sentry boxes, that the surveyor is afforded an opportunity of contemplating the injury done to foundation and surface, and enabled to set about rectifying it, in time for the next upheaval.

This state of things, whereby a freehold in the subsoil has been granted to companies worked for private gain, should not be possible, and the assistance of Parliament, which granted such rights, should fairly be depended upon to enforce the transfer of all pipes and cables into subways constructed for the purpose. The annual expenditure in excavating and filling trenches is enormous, and the saving in this item alone to companies would far more than pay the cost of transferring their pipes and cables to the subways.

The comparisons made with the streets of Continental cities, to the disparaging of London, are frequently exaggerated and in some cases devoid of accuracy—a gross instance being the statement that even in Russia the streets are in better condition and more effectually cleansed. To one who has seen the Nevsky Prospect of Petersburg, with its surface paved in rough-sawn tree butts and cobbles, the narrow bumpy streets of Moscow, and the pestilential lanes of the so-called "Fair" Ground of Nijni Novgorod, the assertion is amazing.

TRAFFIC.

The question of traffic of varying speed traversing the same road or street at one time is a vital one, as it affects the capacity of the thoroughfare enormously. This must be admitted by any one who has seen lumbering wagons crawling along Oxford Street, or several railway vans loading goods in Piccadilly Circus at the busiest time of day. Again, the custom of drivers keeping 2 or 3 feet away from the near side kerb seriously reduces the capabilities of the street, without yielding an atom of good to the driver whose thoughtlessness inconveniences overtaking traffic. Another factor in street locomotion is the interruption caused by omnibuses stopping anywhere to pick up or drop a fare, instead of having definite stations to stop at, selected for their non-obstructive positions. These difficulties are no doubt more acute in the Metropolis and other large centres than in country towns, but still they are everywhere undesirable, and should be subject to police regulation.

EXCAVATIONS.

However thoroughly and conscientiously a trench cut into a road is filled, rammed and consolidated, it is difficult to produce an immediately satisfactory surface, and it is still more difficult to tell what the settlement will be after traffic and weather have had time to affect it. Instances of improperly filled trenches, sewers disturbed, and brickwork of arches and culverts cut into and pipes driven through, will occur to most engineers who have had control of roads. As an instance, the author had recently to cut out the pipes of a company who, although warned against doing so, had removed portions of the brickwork from culvert arches on a main road, and inserted their pipes; and yet the same company, unchastened by this lesson, and although warned, soon afterwards laid their pipes in a district road outside their area of supply, whence they were extracted by means of chains and a traction engine.

It is not unreasonable to suggest that, without exception, the restoration of all roads cut into by trenches should be the duty of the authority responsible for the maintenance of such roads, and at the expense of those causing the disturbance.

TRAMWAYS.

The benefit which tramways confer upon the working and middle classes by conveying them between the suburbs and business centres of large towns, and the important part they must play in solving the knotty housing problem, cannot be questioned or minimised, but the general public is entitled to expect that, as an equivalent for the practical monopoly created over a certain width of road, the facilities for other traffic are in no way curtailed, and that the cost of maintaining the public highway is not increased.

Taking the width of a double line of 4 foot 8½ inch tram-lines and the 18 inch overhang margins, at 16 feet (all maintainable by the owners of tramways), it is obvious that, if laid on a 20-foot country road, a considerable additional width is necessary. In arriving at this it may be pointed out that the minimum width of road at each side, if made of macadam, should be 12 feet if effectual consolidation by a steam roller, 6 feet 3 inches wide, is to be attained, as the work is never well done unless the weight of roller is equally distributed on both driving-wheels, and sufficient width is provided to enable the driver to keep such weight so distributed whilst completing his work by edging away from side towards centre, a wheel-width at a time. If narrower this could not be attained unless one wheel was on the granite setts of the tramway, which would result in a depression in the macadam under the remaining wheel. The author is of opinion therefore that no country main road should have a double line of tramways placed upon it unless its width is at least 40 feet. Even under these conditions it is evident that additional expenditure would be thrown upon the road authority, in maintaining the metalled roadway immediately adjoining the harder granite setts of the tramway.

TRACTION ENGINES.

The growth in traction traffic, heavy and light, has been very rapid of recent years. The comparatively small number of bridges and short length of roads which, under the 1894 Act, were suggested for scheduling against heavy traction. indicate that road authorities generally appreciate the fact that this increase must be expected and provided for. It is when country roads and lanes, which were not constructed for nor traversed by traction engines, are suddenly utilised by such traffic that trouble occurs, and, unless reason and forbearance are exercised on both sides, leads to litigation, which the recent alteration in the "extraordinary traffic" clause has by no means simplified.

A very substantial improvement in the feeling towards traction engines would have been effected had a suggestion made to the Parliamentary Committee responsible for the 1894 Act been adopted, i.e. that all drivers should be licensed. Traction engine owners can hardly realise the amount of prejudice created in the minds of the travelling public by stupidly aggressive and inconsiderate drivers; one such "undesirable" does more to retard the growth of better feeling among the public than a dozen considerate drivers can efface.

Motor Cars.

As he has been requested to avoid encroaching upon the topic of motor cars in consequence of arrangements made for a paper to be read on the subject later in the session, the author will confine himself to a few general remarks bearing on the road question.

In addition to the advantages which a smooth surface gives for all traffic, it is undoubtedly true that for fast travelling pneumatic-tyred machines an equal if not greater benefit is obtainable if their tendency to raise dust and splash up mud be counteracted as much as possible. To attain this end it naturally follows that the less dust on the surface or in the fabric of road — for large pneumatic tyres undoubtedly do remove detritus from the interstices — the less the inconvenience. From a surveyor's point of view, the question arises as to what extent he is justified, after exercising due care in the selection of the hardest materials and rolling with a minimum of binding, in incurring additional expenditure in the removal of dust which no other traffic creates or disturbs, and which, to a moderate extent, is essential to the cohesion of a road surface, flint especially. This appears to the author to be one of the crucial points in connection with this fast growing traffic, of which he has frequently availed himself, and, in common with the general body of surveyors, recognises as an industry which from a national point of view deserves ample encouragement, and may possibly revolutionise methods of transport when prices are lower, and all the more rapidly when owners secure the abolition of the pace limit fixed in experimental days—now more honoured in breach than observance—by acquiescing in the adoption of means of identification of those enthusiasts to whom the pleasure of travelling at excessive speeds is of more importance than the public safety.

HILLS.

One of the improvements suggested by advocates of fast traffic is that of reducing gradients on hills, and obviously this would benefit horse-drawn and bicycle traffic equally, indeed more so, judging by the ease with which motor-cars recently ascended Dashwood's Hill, a mile in length, with a gradient of 1 in 12, at 25, 30 and even 40 miles an hour. In dealing with this question the author has found that, in addition to the expense involved—and this is far in excess of what is estimated by a casual observer—there are various questions and interests to consider. As an instance, one case where the cutting down of the upper portion of a hill and utilising it for extending the foot was decided upon, the adjoining owner threatened an action to restrain, and asserted that the water for his house and land gravitated from this hill, and that if it were lowered he would be deprived of his supply.

If a general scheme for reducing gradients is advocated, it seems only equitable and right that the cost should be a national charge, as otherwise the ratepayers in hilly neighbourhoods like North Wales and Cumberland, would, through no fault of their own, be penalised for the benefit of those living in counties where the configuration owed its flatness to nature alone.

The following figures relative to tractive force necessary for surmounting hills of various gradients are the result of experiments made with small models, a miniature wagon being drawn up an incline of varying gradients by means of a weight attached to a cord passed over a pulley; and although the results differ from theoretical calculations, they may be worth further consideration and testing. The figures are calculated upon the power which a horse exerts in drawing a cart weighing 10 cwt., containing a load of 1 ton, on a level road, at 2½ miles an hour.

	cwt.
A horse on a level road moves	30·0
" an ascent of 1 in 40 moves . . .	21·75
" " 1 in 30 " . . .	19·37
" " 1 in 20 " . . .	15·19
" " 1 in 15 " . . .	12·75

Increased Means of Communication.

A curious omission is observable in the assertion so frequently made that, although population and trade have grown, there has been no increase in means of communication since turnpikes were abolished. Surely the network of railways constructed since that date has added very materially to the means of communication, and proportionately relieved the congestion in road traffic. With reference to the construction of new roads and thoroughfares, it is hardly necessary to point out that neither county nor district councils have power to construct new roads, that the former cannot declare a new road to be a main road until it has been adopted as a public highway by the local authority, and that such local authority cannot contribute towards the cost of making a new road except by a majority of two-thirds of its members.

It seems to the author that country main roads, taken generally, are not too narrow if tramways, motor, and cycle traffic are excluded, and that if additional room be provided for this undoubtedly important and growing section of road users, the difficulty would be met. The suggestion to make separate and distinct roads or tracks away from existing highways for one section of traffic cannot be entertained unless it is intended to levy a sufficient tax upon such traffic to pay for construction and maintenance; and even then the adjustments or exemptions from the usual highway rate could not be equitably arrived at unless this traffic was debarred entirely from using ordinary roads—a restriction which, until special tracks were as numerous as roads, would palpably cripple its usefulness.

As the best of granite with a minimum of binding will wear and make dust, which Jupiter Pluvius insists upon liquefying, fast traffic, which undoubtedly disturbs it when ordinary traffic does not, should have a hard, dustless, and well drained track added to the width of existing roads for its use. This would be the cheaper to construct, as a lower price (if any) would have to be paid for open roadside wastes, than for strips of valuable property, the materials could be delivered more cheaply than if an entirely new road was being made, and the cost of maintenance and supervision would be enormously reduced if done concurrently with that of an adjoining road by one authority.

The financial aspect of the question is an exceedingly difficult one, requiring thorough consideration in the interests of a growing industry which deserves the fullest support, consonant with the avoidance of injustice to other industries of vital importance and great magnitude. It appears to the author that the national purse should defray the cost of widening existing roads and making special tracks for fast traffic (or making new roads altogether); that the cost should include compensation for injury or depreciation and be reduced by repayments for enhanced values of frontages and betterments; that the upkeep of tracks should be met by a graduated Government tax per horse-power per car or cycle; and that the authority in charge of adjoining road maintaining such track satisfactorily receive a Government grant in proportion to the length under its control. By constructing thoroughly good tracks the maintenance cost of which would be low, the tax per car could be kept within very moderate limits, and as motor traffic increased, would necessarily diminish.

TURNPIKES.

The alternative to this method of defraying the increased cost would be a modified form of turnpikes; but this, although undoubtedly the fairest way of making actual users of roads pay for their upkeep, is quite out of the question, being contrary to all modern principles of personal liberty and freedom, open to many serious abuses, and its revival would lead to revolt. Only recently a toll bridge carrying the Bath road over the Thames came under the notice of a public-spirited ratepayer (who had a few years before succeeded, after much litigation, in freeing another Thames bridge), and, as the result of a public inquiry, it was found, by the frank admission of the authority implicated, to have provided funds for objects entirely foreign to its maintenance and the road over it.

AMENDMENTS IN HIGHWAY LAW.

That the Highway Acts require consolidating is only too obvious to those relying upon them for guidance in their daily work; and in addition there are amendments to make which have long ago commended themselves, such as the necessity for giving a county or rural district council power to prescribe a greater distance than 15 feet from centre of road for hedge or tree planting; the need for power to keep buildings back to a regular line set out with due regard for possible widenings; the imposition upon all road authorities of the duty of making good all excavations in their roads, and charging to those responsible therefor; the making illegal of farm or other carts coming off ploughed or other dirty land on to roads until the wheels are moderately cleaned; the clearer definition of what road can be declared a "main road"; the more lucid explanation of "extraordinary traffic" and the person or persons liable for damages caused thereby; the amendment of section 11 (2) of the 1888 Act, whereby the anomalous position is created of giving one authority the power of spending on its main roads what it deems right, and recovering the greater part of the cost from another authority, which can only appeal to the arbitration of the Local Government Board, whose award gives no reasons or figures for future guidance. This might be accomplished by relieving the larger urban authorities of payment of their share of the county road rate, and paying them directly their due share of the Exchequer contribution account, thereby enabling them to maintain their main roads as the larger county boroughs do.

Government Control.

The question of Government control is one which the author considers practicable if all public roads are included and are directly repaired and maintained by a Government department; but it is open to serious doubt, even if this wholesale suggestion were carried into effect, whether this would accomplish, at any thing like the present cost, the work which has been done of recent years by county and district councils whose members, selected from the most prominent and capable local administrators, have freely given their time and knowledge to the public service.

It is quite obvious that no other method than nationalisation of all roads can possibly distribute equally the burden of maintaining the public roads of the kingdom, as there are no two counties, no two districts, where the conditions as to mileage, cost of maintenance, area, rateable value, agricultural land, etc. are precisely equal. County A, owing to its distance from a quarry, has to pay 12*s.* per ton for its granite, but county B can obtain it for 8*s.* County or district C is rural and has a small rateable value, but has to maintain a road running across it from one large county borough to another, and monopolised by such traffic which pays nothing directly towards its maintenance. County or district D has an exceptionally small length of roads, but uses those of adjoining authorities extensively; county or district E, being very badly served by railways, has to increase its expenditure 5, 10 and 15 per cent. in hauling materials a greater distance from stations to roads.

Another less ambitious method would be to create one authority in each county responsible for every public road, whether subventioned by the State or not. This would equalise rating in each county, but not give to counties of rural and small town character that relief which should be their due if complete equality of rating is aimed at. To the supervision which the Government department might impose in the event of a contribution being subject to their approval, there could be no reasonable objection by any authority or officers who had endeavoured to carry out their duties in accordance with the requirements of the Acts of Parliament constituting them.

INCIDENCE OF TAXATION.

In discussing the means of raising the enormous sums which any extensive system of road construction or enlargement would necessitate, it must not be forgotten, when due attention has been paid to the fact that some 4,000,000*l.* capital is invested in the motor trade, that the capital sunk in agriculture in England and Wales, estimated at 7*l.* per acre, amounts to 196,700,000*l.*, and that, being far and away the most extensive industry, and employing more labour, in spite of bad times and preferential rates favourable to foreign produce and stock, its claims to fair and equitable treatment are undeniably great.

If motor car makers would only produce, at reasonable prices, those long promised machines and vehicles for revolutionising agricultural work, and reducing the cost of raising and transporting produce, they would make powerful allies among those who now fail to see that mechanically driven vehicles are of any benefit to their industry.

DISCUSSION.

The PRESIDENT said that he had great pleasure in asking the meeting to pass a very cordial vote of thanks to Mr. Thomas for his excellent paper. The subject was one of great importance at the present time, and he knew of no county surveyor in England who could better deal with it than Mr. Thomas could; and his paper would be all the more appreciated when it was known that it had been prepared at some personal inconvenience, for the author was an exceedingly busy man.

The vote of thanks was carried by acclamation.

Mr. E. J. SILCOCK said that Mr. Thomas had given them a very interesting paper, and he thought that the case which the author had made out for the county councils was a very strong one. He was not one of those who believed that every country and every age but one's own was the best. He had a strong suspicion that the roads in the "good old days" were a great deal worse than they were now, and he was quite certain that in a great many districts there had been many improvements since the main roads had been taken over by the county councils. He regarded the case in favour of the control of roads by the county councils as unanswerable. It was sometimes said that it was better to decentralise, and that the man in the district knew more about the control of the roads in his particular parish than a county surveyor who lived at the capital of the county, perhaps forty or fifty miles away. But he did not agree with that view. He believed that the direct control of the roads by the public authority was a proper system, and he believed that the county councils were in as good a position for the work as any authority which could be devised. He questioned whether, if there was a nationalisation of the roads, and all the roads of the country were administered from Whitehall, they would be kept as well as they were now. Under the present system there was proper supervision, and at the same time the authority was a sufficiently large one to deal with the question of the roads on broad lines. He hoped that before long the system of direct control of roads by county councils would be extended from the present main roads to every road in the country.

The only exception he would make was in the case of the non-county boroughs. He agreed with the author on that point. Where there was a non-county borough of anything like a reasonable size, it should be permitted to maintain its own roads, and it should be put in the same position as the county boroughs now were. He had had some little experience of the difficulties of dealing between non-county boroughs and county councils, and he knew that there was very often a considerable amount of dissatisfaction as to the proper contribution to be made by the county to the borough. He thought that that would be done away with by the suggestion made by Mr. Thomas.

He agreed with the author in the view that the placing of a tramway upon a narrow road ought not to be allowed. He was very sorry to see that the Light Railway Commissioners, in the execution of their responsible duties, sanctioned in many cases the construction of light railways, which were to all intents and purposes tramways, upon roads which were very much too narrow. Perhaps he did not go so far as to say that the carriageway of a road should be 40 feet wide, but he was of opinion that a double track of tramway ought not to be constructed in a road which had a total width of less than fourteen yards.

There were one or two points in which he might be disposed to join issue with the author, who had given some very interesting figures with regard to the wear of 50 yards of a particular road from a certain number of collars. He thought, however, that Mr. Thomas was rather a bold man to make a positive statement to the effect that, therefore, the wear from 100,000 collars would be any definite amount. He (Mr. Silcock) has analysed a great many accounts for road maintenance, and he had never been able to find a sufficient similarity in the costs of different lengths of road to enable him to form anything like a definite opinion as to a standard of wear for a given amount of traffic. He believed that there were so many factors which went to make up the wear, that the number of collars which went on the road could not be taken as the true criterion. Further, he was disposed to think that the length of time occupied by the collars in traversing the road had a very material effect upon the amount of wear. The amount of wear would be increased more rapidly than the direct proportion of the rate at which the traffic went over the road. For instance, a town road, carrying five times the traffic of a country road, might possibly cost more than five times as much to be maintained. He would commend that view of the case to the meeting.

One point upon which he should like to hear the opinion of the members was the question of rolling. Mr. Thomas had told them that in his practice he did a great deal of dry rolling before he put the water on the road. With all deference to Mr. Thomas's opinion, he (Mr. Silcock) was inclined to think that dry rolling was a mistake. The rolling of material on the old surface of the road when it was very dry and hard, was bound to result in the crushing of a large proportion of the stone which was put on. The object of steam rolling was to press the material into position on the old road without crushing it, so as to make it form part of the old road surface; and undoubtedly that could be done best when the old road surface had been thoroughly wetted and made as soft as it was possible to make it. He believed that better results were obtained by thoroughly wetting the road before the rolling commenced. At all events that was the practice which he had always followed; and he had in many cases seen a great deal of road material crushed and pulverised, in consequence of the watering not being done before the rolling.

Another point was the improvement of the hills. Mr. Thomas has suggested that that should be made a national charge, but he (Mr. Silcock) did not follow Mr. Thomas's line of reasoning. It might be perfectly true that, if the county councils were to carry out the improvement of the gradients, the counties in the hilly districts would have to spend more money on roads than the counties in the flat districts; but there were many things which one had to put up with in consequence of going into a certain district to live. If a motorist wanted to go and "scorch," he did not select a hilly district to do it in, but he went into the Fen country or some district which had flat roads. He (Mr. Silcock) did not at all think that, because a man selected a hilly district to live in, that was any reason why he should escape the cost of reducing the hills to a proper and reasonable gradient. It might just as well be argued that the drainage of the Fen district should be made a national charge. If a man chose to go and live in a town, he had to pay lighting and drainage rates, and rates, for a great many things which were imposed upon him because he chose to live in that particular place; and the author's argument might be equally well applied to those charges.

Mr. PERCY GRIFFITH said that while he appreciated the excellence of the paper, both in respect to its wide range and the practical manner in which every point had been dealt with, he ventured to suggest that the author, in one branch of his topic had gone a little too far. Under the heading of "Metropolitan and Town Streets" the author, referring to the numerous authorities "to whom Parliament had in its wisdom sold the public birthright by granting power to dig and delve therein at their convenience and leisure," said, "This state of things, whereby a freehold in the subsoil has been granted to companies to work for private gain, should not be possible." Then the author proceeded to recommend the construction of subways, stating as a fact that "the annual expenditure in excavating and filling trenches is enormous, and the saving of this item alone to companies would far more than pay the cost of transferring their pipes and cables to the subway." The expressions he had quoted were so remarkable that he (Mr. Griffith) was disposed to accept them as intended for humorous exaggeration. His own associations being both with companies' undertakings and with those of local authorities, he could speak without prejudice, and he could not agree that any company could be said to have "received from Parliament a freehold in the subsoil for private gain." Parliament was not in the habit of granting any powers with regard to public roads for purely selfish purposes. Our gas, water and electricity companies existed for the public good, as well as for the purpose of private gain, and Parliament would not have given them any powers whatever unless satisfied on that point. A company did not open a trench in the street for its own private amusement or directly for purposes of profit, but for the convenience of the public who were its customers; and, speaking broadly, he might say that companies were no more in the habit than local authorities of unnecessarily opening roads or leaving trenches in a bad condition. In addition to that, companies were invariably under the control of authorities such as the author himself represented. The surveyors of roads had most drastic powers with regard to the condition of trenches opened by companies, such work being always followed up by the surveyor or his representative in a very critical manner; and he ventured to suggest that under such circumstances the condition of the trenches was likely to be more strictly looked after even than when they were opened by the local authorities themselves without any supervision by a higher authority. He wished the author to understand, however, that he was not expressing a view, either one way or the other, on the general question of control. He and others present were members of the public, and a defective trench was a very distressing thing to them all, whether concerned merely as foot passengers or as engineers advising a client in connection with it. They were all anxious to see the roads dealt with sensibly and in a practical way, but he confessed that he did not like expressions quite as strong as those which he had quoted. Perhaps the author would see his way to modify some of the more extreme views which he had expressed in the paper.

Mr. HOWARD-SMITH said that Mr. Silcock had suggested that the ideal width of a road, in which there were to be two lines of tramway, should be 14 yards. That figure should be modified; for, with a double track and the statutory width of 9 feet 6 inches from the kerb to the nearest rail, there would only remain sufficient for a 5-feet footpath on each side, which was manifestly insufficient. He agreed with the author that the statutory width of 9 feet 6 inches for the space between the rail and the kerb was exceedingly narrow, and the regulation required amendment. In his opinion the width of carriageway whereon a double line of tramway was laid, should not be less than 36 feet apart from footways for a suburban or county arterial road, while in towns it should be increased to 45 feet, which would for one thing admit of tradesmen's carts standing at shop doors. Tramways were often reviled on account of the alleged obstruction and general inconvenience they caused upon a road, but his experience was that that view was greatly exaggerated; and, except where they had been allowed to be laid in far too narrow carriageways, they did a great deal of good in assisting the flow of vehicular traffic. Again, they were usually means of a considerable amount of street widening being effected, of which they bore the cost. As an instance, he might mention that for one very large system of tramways with which he had been professionally associated, the principle had been adopted that there should be a minimum total width of 50 feet provided throughout all roads whereon a double line of tramway was to be laid. That allowed a 9-feet footway on each side, and a distance of 9 feet 6 inches from the kerb to the nearest rail; and, as a fact, the cost per mile of the road widenings and contingent works amounted to three times that of the track.

He quite agreed that, under the Light Railways Act, tramway tracks had been permitted to be laid on roads which were totally inadequate for such a purpose. He knew of a case in which lines had been constructed through an urban district of large population, the main street of which had a width of only 15 feet between the kerbs, and the consequence was that not only was the conduct of business adversely affected, but a person walking on the footway with an open umbrella could not pass a car as the footway was only 3 feet in width and the tramcar actually overhung the kerb.

Referring to the remarks of Mr. Griffith as to the laying of mains by a local authority not being done under supervision, it was not the case in practice that such work when done by authorities was not done under supervision. As a matter of fact one official, the surveyor, was looked upon as responsible for the condition of the surface of the road; and if he did not himself execute the necessary works of restoration, he carefully supervised it when it was done by another municipal official. He was sure that the members would appreciate the thoroughness with which Mr. Thomas had presented the subject to them.

Mr. Douglas Mackenzie said that the author had spoken with natural, but, he thought, undue modesty with regard to the Bucks road system. That system had worked in Buckinghamshire for a great many years with most excellent results, and those persons who used the Buckinghamshire roads would, he was sure, agree with him that there were no roads which were in better condition than those of Buckinghamshire. He believed that the failure of the system was due to legal difficulties, and not to any fault in the system itself. He was sure that if a similar system had been adopted in many other counties, they would not be confined to main roads when they wanted to make excursions. He could point out other counties in which those who wanted to make excursions must confine themselves to the main roads, because the other roads were impassable. In Buckinghamshire even the bye-roads were in most excellent condition. In some of the neighbouring counties, as Bedfordshire and Hertfordshire, the roads were maintained on quite a different system, which, he was sure, cost a great deal more, though he had not had the figures put before him. In those counties all the roads, with the exception of certain urban roads, were maintained by the county council. Even the bye-roads had been "mained" with a view to the county council maintaining them, and the surveyors of the district councils had no authority over the roads at all. That had led, at all events in Hertfordshire, to an enormous expenditure without adequate results. It was a matter of regret that the Bucks road system had fallen through in consequence of legal difficulties.

One point had been raised in the discussion about which he should like to speak. It was the fact that tramways brought in their wake improvements with regard to roads. Persons objected to the presence of the tramcar upon the road, and they thought that the presence of the steel rail was a very serious cause of accident to other vehicles, but they must admit that the tramway, having become necessary, one result of its adoption was that great improvements had been brought about in many roads. If a tramway was carried, say from Windsor to Slough, there would be great improvements carried out which were very necessary to certain bridges and other portions of the road. Wherever tramways were extended, improvements came in their wake, and those improvements were a great advantage to all classes of road users. They must admit that a tramway generally conferred benefits in various directions, though they objected to the presence of the tramcar and of the steel rail.

Mr. H. GLYNN WARNE said that where the county roads were maintained by the district councils, the supervision by the county surveyor was a very real one. The system carried out in the county of Devon was uniform as far as it was possible for any system to be uniform, though he thought that, possibly, far better results would be obtained if the road had been maintained directly by the county council itself. According to his experience, nothing was so likely to produce good results as direct maintenance by the authority who was really responsible.

He agreed with Mr. Thomas that the stones were better as a rule when they broke fairly cubically; but he knew of one stone which broke cubically but had a tendency to break down into smaller cubes, and ultimately into very fine dust which was still cubical. It was necessary to be very careful in choosing stones. The stone to which he referred appeared to be very good. It withstood a great crushing power and was splendidly square, and, when it was first set in a road, it made the road appear as if it had been paved with small cubes; but the surface soon became pitted and worn. That result was no doubt due to the fact that the cementing material between the cubes was not sufficiently strong to hold the many minute cubes together.

With regard to the use of flint, he believed that that material made a very good road where the ground was very wet; but, where the ground was dry and there was a gravelly subsoil, the flint very soon pulverised and became blown away, and there was a tendency for it to leave little sharp pieces sticking out.

In his district many complaints were received from bicyclists as to these sharp pieces of flint cutting through tyres, even when there was no dust about, and, in fact, more frequently when there was no dust than when there was a large quantity of dust.

With respect to excavations, in his district most of them were carried out by the engineer of the district council. His experience was that when the engineer filled his trench, he did it most carefully, and he gave ample notice of his intention to make the excavation, and always left the road in very good order, frequently much stronger than before he broke it up. But he did not always find the same thing done by companies, Those bodies sometimes failed to give adequate notice and they did not discriminate between the hard core and the surface metal, and sometimes they put what should be on the surface right down in the bottom of the trench, and what should be at the bottom was put to form the surface of the highway.

He differed from Mr. Silcock with regard to dry rolling. His experience was that the dry rolling of the material was very beneficial. He found that, if he did not dry roll, he had to use a very large quantity of binding material which afterwards had to be rolled out again; and, if that binding material was not rolled out and swept into the sides, the road did not wear very well, and it was always muddy in wet weather and always dusty in dry weather. Mr. Silcock said that he liked to have a road fairly soft, but he (Mr. Warne) found that he did not get a very good road surface when the road was soft, and sometimes, in fact, he had to coat a road with roughly broken material in order to get sufficient strength to enable it to bear the roller. The roller made the best work upon a surface which was comparatively hard, and which had not been disturbed too much by scarification. The scarifier always scarified most those roads which least required scarifying. On account of their being much more soft than the better roads, the tines of the scarifier went more deeply into the surface, and so disturbed what they would be glad to keep in position.

Mr. B. D. HEALEY said that in the early part of his paper the author said it was well to know that all the materials bought had been actually used. One of his (Mr. Healey's) experiences, forty years ago, in that respect was rather disappointing. Materials were sent to the store-yard without any check as to whether they reached the depots for which they were intended. He introduced a system of booking which showed what materials were brought in, and how they were used, and how much of each particular material remained on hand; and that system had worked very well, and was still in use.

With regard to the substitution of harder material in road-making, of course as traffic increased it was essential to get material of a harder kind. Basalt, syenite, and some kinds of granite, if properly rolled as suggested by the author, made the roads very durable; and it was truly economical to make the roads in that way. It was always evidence that the county surveyors were keeping up to the requirements of the time, when they used superior kinds of material, not only for the main roads but also for the subsidiary roads in the different districts.

As to the remark made about the use of blast furnace slag mixed with tar, he did not agree with it. The slags from iron-works contained various proportions of lime, and, until they had weathered considerably, the road-maker never knew what he was dealing with. Some parts of the slag, especially in winter on a dewy morning, showed themselves very friable. The furnaces from which those slags came had been overlimed, and there was evidence of the fact in the blocks of slag falling away. He had found that asphalte macadam properly laid made a very durable and substantial surface, and after a little while it formed a very ideal surface, especially if laid with limestone. The next best thing to limestone was syenite. Syenite was suitable for fairly heavy traffic, but limestone should not be used for heavy traffic.

As to the size of the stones, he thought that a two and a half inch ring was about the largest that should be used, but in exceptional cases it might be desirable to use larger, and a covering of the smaller size named by the author.

There was no doubt that care should be taken in the selecting of materials, and that, as the author had said, the materials should be rolled in thoroughly well. Although that cost a little more at first, it was truly economical.

Statistics were given by the author as to the wear of roads. They agreed pretty well with observations which he (the speaker) had made in the same line about forty years ago, but his observations were made on paved roads on which blue sets from Wales were used. He found that the surface wore down $\frac{1}{8}$ of an inch in four years. The carriageway was about 15 yards in width, and the heaviest traffic of Liverpool passed continually over it. He thought those figures compared favourably with the wear on the roads which the author had mentioned.

As to steam rolling, no one would think of rolling in a road 6 inches deep at once with blue stone. There was far greater loss of material by the rolling, if the material was laid too thick, than if it was put on in a thinner layer. As to the practice mentioned by the author of removing the scarifying material he thought that it was an excellent idea. It was one which he had followed himself, and he had seen many other surveyors adopt the same method. The old-fashioned system of using ashes or gravel, or sand, or even soil, was pretty well exploded.

With regard to street work, he thought it needed to be done much more carefully than it was. That applied to the simple problem of laying wood blocks. No knot in a wooden block should be laid nearer to the surface of the road than 2 inches if the block was 5 inches. That would settle the question for a good many years, and the block would wear down evenly. If there was a right side and a wrong side to a block, the wrong side was often put upwards.

The question of granite sets or hard stone sets of any kind was a most important one. Such a thing as a shilling a yard, more or less, in cost should not be considered in connection with having the sets very well dressed, especially on the face, and not much less so on the underside. If a set had not enough surface to stand upon, it would not stand upright, and if it was not dressed well on the surface it would not wear well.

So much had been said with regard to the work of the excavators and the cost of water and telephone, and other conduit men, that, instead of what was said being allowed to have its proper weight, it seemed to have too little weight. Anyhow, he thought that the matter should never be forgotten, and that in due course some remedy would be found for it. The remedy in time would, no doubt, be subways, which had been proposed. But his opinion was, that whenever the time of conduits came, one conduit would not be sufficient in streets such as Fleet Street or the Strand, but there would have to be a conduit on each side of the road. Otherwise the road would have to be broken up almost as frequently as before for branches. He was strongly of opinion that a duplex system of conduits would have to be adopted. The great difficulty would be to fix upon an authority for carrying it out. Probably in London the authority would be the County Council.

Mr. W. Nisbet Blair said that the difference between his experience in the traffic of a town and the experience of the author of the paper on country roads was very great ; but he knew something of the latter, and he fully appreciated the very excellent condition in which the main roads of the country were now kept. He used the term "main roads" in the ordinary sense. On the country roads the traffic could go along without effort until there was a rising gradient, but as soon as it got near a town it came on to rough roads. He did not know what would be the effect on some of the country roads if they had to carry, what he considered to be the bane of all street traffic, namely, omnibuses. They had 3-ton omnibuses on narrow wheels running at a considerable velocity, and that undoubtedly put a severe strain upon a macadam road. Tarred macadam had been spoken of as giving a very good surface, and it did so where the traffic was light and not confined to a particular wheel track. But he had tried it in London on streets which had considerable traffic with omnibuses at frequent intervals, and he had found, to his great disappointment, that the material was all alive and could not be kept down at all. It was simply rolling about. It gave way under the heavy traffic of omnibuses.

With regard to the size of the macadam, the difficulty was to keep it down to the nominal size of the screen. A stone which passed through a 2-inch screen might be 4 inches long. It was quite impossible to apply the gauge to every stone. It was said by Macadam that the stones should be rejected if they could not be got into the mouth, but it would be impracticable to apply such a test as that to a ton of stones. Small stones unquestionably were better than large ones for light traffic.

He must support the views of Mr. Thomas as against the views expressed by Mr. Griffith. Of course, the question of the existence of a company depended on two factors. A company would never be authorised if its object was not for the public good, but there would never have been a company promoted if it had not been for private gain. Therefore both aspects of the matter were to be considered. They would not imagine that any of the London water companies existed solely and entirely for the privilege of supplying water to the water consumers of London. He had had experience with a good many companies, and also with the various departments of the body which he served, and he could not say that, as regarded his experience with the roads, he had had any greater difficulties with the water companies than he was having with his own electricity department. His practice was to send to each of the companies a list of the macadam roads which he proposed to reconstruct and the order in which they would be dealt with, and to ask them to do forthwith any work which they might have to do upon them. They frequently replied that they did not want to do any work, but that they were obliged for the information. The same plan was adopted with the electricity department, and it had happened that that department had replied that they had no intention of doing anything in the roads named, but they had opened up a road from end to end within a few weeks of the completion of the reconstruction. That was aggravating, and one could never make a good job of the road under such circumstances.

He congratulated the author upon a statement in which he said that "the members of county and district councils were selected from the most prominent and capable local administrators." His (Mr. Blair's) experience had not always been as fortunate as that.

Mr. Ernest Benedict said that, speaking as only an ordinary civil engineer and not as a road engineer, he must say that Mr. Thomas's paper was one of the best that he had come across. It thoroughly carried out the principles upon which he (Mr. Benedict) has been brought up, and that was to use a very hard material broken small, and above all to use clean and sharp binding.

One thing he missed in the paper was a reference to the profile of roads. Upon that subject he had his own opinions, and that was that, as a rule, the profile of a road was much too steep towards the gutters, and that that was one reason why heavy traffic would not go near the curb. If it did so, it overhung a great deal, and the traction was much heavier, and it was difficult to get back towards the centre of the road.

With regard to tramways, he must say that they were treated as a kind of *bête noir*, and everybody's hand seemed to be against them. It seemed to him that roads were made for the purpose of carrying traffic, and that tramcars were necessarily part and parcel of the traffic. At the general meeting of the Tramways Association, a body of which he was secretary, it was mentioned that the Isle of Thanet tramways had taken 400,000 passengers a year away from the railway, but that they had carried 4,000,000 passengers a year more than the railway had ever carried. That fact showed that, in that particular case, the tramway was wanted. Let them imagine the enormous amount of vehicles and the enormous number of horses which would have been required, and which would have pounded up the road, to take these 4,000,000 passengers. That traffic was carried very easily by the tramways, with no detriment at all to the roads but rather to their advantage. He thought that, when that was considered, it must be confessed that tramways were not such a nuisance as they were generally made out to be. Then, again, as to the charge that they monopolised the roads. That was not true. If the traffic was very heavy, and the tramcars ran very often, that fact showed that they were required; and if the cars went very seldom they could not be a very great nuisance. To whom were they a nuisance? Were they a nuisance to the fast traffic? The fast traffic could get by them, or they might be allowed to go faster. Were they a nuisance to the slow traffic? Well, the slow traffic was a nuisance to the other kinds of traffic, just as much as it was to the trams. He could not see why there was such a dead set against a tram-line, unless it was for the purpose of forcing the tram companies to do those widenings and other improvements of the road which were very nice, but which, if they were necessitated by increased traffic, ought to be done by the road authorities. The proprietors of cabs and omnibuses were not required to widen and improve the roads. If, for instance, there was a great accession of cab traffic to a new railway station, were the cab-owners called upon to widen the roads? He did not see why tram companies should be called upon to contribute any more than the proprietors of any other public conveyances.

The President said that Mr. Thomas had given them an excellent survey by which anyone could understand what was meant by a main road. He did not suppose that, after the explanation which the author had given, there would be confusion in the use of the term "main roads." Mr. Thomas had also given excellent reasons for the management, control, and maintenance of main roads being vested in the County Council. If the main roads were nationalised, there would not be sufficient individual control over the enormous lengths of roads which would have to be maintained by a department of the State. His own experience was that, if the work to be done was spread over too large an area, the department could not have sufficient knowledge of all the details. He did not think they could have a better system than that which obtained at the present time with regard to the main roads of a county—that of their being administered by the county authority. He did not think that anyone who travelled about the country could say that the main roads of the counties were not maintained better now than they were before the county councils came into existence. He mentioned, in his inaugural address, that one reason of the improvement was that harder stones were being used, and that the work was being done under more experienced men. Men who were really specialists in road making and maintenance were being employed. The present condition of the main roads of the country was very strong evidence in favour of the skill and organising power of those county surveyors who had the control of the roads, and he thought that it would be impossible to devise a more satisfactory system of dealing with the main roads than that which was in vogue at the present time.

He was much obliged to Mr. Thomas for calling attention to the misquotation of the remarks which he (the President) made at the Annual Meeting of the Municipal and County Engineers, held at Leicester. He had no complaint to make of the old roadmen in the country. He thought that the secret of the skill which those men displayed in the repairing, patching and general maintenance of the main roads, was that they were not mere casual men who had been employed in some other kind of work, but that they had been engaged in road work from their youth. Mr. Thomas had referred to the same men having been engaged in the work as young fellows, and their fathers before them having been engaged in the same way. He (the President) was a believer in heredity and in the hereditary transmission of qualities. The maintenance of roads was not unskilled work. It required judgment, and the man who was required to repair a road properly must be a man who had some amount of intelligence. He was sorry that men of that class were scarce in London, and that the percentage of men who were able to repair a road properly was very small indeed. He certainly thought that the county surveyor in country districts had an advantage over his metropolitan *confrère* with regard to obtaining men suitable for the work.

He agreed with Mr. Thomas in his remarks with reference to the rolling and binding of the material, which bore out what he (the President) had said in his inaugural address.

He could not agree with Mr. Silcock that dry rolling had a destructive effect. It had always been his (the President's) practice to roll a road dry as soon as the material was put upon it. Dry rolling caused the stones to be sent down to their proper position and to get a firm bed. After that, the road should be well watered before any binding material was brought upon it. In fact, the binding material should be brought on only in the very last stages. By such means they could keep away that excess of binding material which many roadmen, especially in London, were too fond of putting on the roads. The driver of the steam roller liked to have the road well wetted before it was rolled, because the wetting made the rolling of the road a comparatively smooth and comfortable task, whereas dry rolling gave him a shaking.

He hoped that those who had to consider the question of main roads would learn something from the paper, and that those who were in the habit of criticising road maintenance, probably without due thought, would find in the paper something which would enable them to take a more reasonable view of main road maintenance than they had hitherto held. He thought that the views which had been expressed by Mr. Thomas were remarkably sound, and they could not have come from a higher authority, or from one who had a more practical experience of the work about which he had written. Personally, he thanked Mr. Thomas very much indeed for the very excellent contribution which he had made to the literature of main road maintenance.

Mr. R. J. THOMAS, in reply, referring first to the remarks of

Mr. Silcock, said that he did not imply in his paper that the wear would always be in the given proportion to the number of collars. He had simply given the figures of what happened in a particular instance under stated conditions.

With regard to dry rolling he had unfortunately to differ from the view expressed by Mr. Silcock. He found that by dry rolling they not only secured the due compression of the stone, and created binding more effectually, but also discovered any depressions which required additional stones before water and binding were added.

As to Mr. Griffith's remarks, he (Mr. Thomas) was sorry that that gentleman had taken so much to heart what he had said about the companies opening the roads. He did not know that he could modify his statement very much. His view was that it seemed a frightful waste, whether of public or of private money, to have the constant excavations done without rhyme or reason at various times. The moment a road was put down, it was cut into for various purposes. By a system of subways extending under the whole street, the pipes, private and public, could be laid and the connections made direct with the houses, without disturbing the surface of the street at all.

He did not agree with the remarks which had been made with reference to the Bedfordshire and Hertfordshire roads. Bedfordshire was his next county, and the roads there were in excellent condition. As to Hertfordshire, he was not quite so clear, but that council was not responsible for the state that the roads were in when they took them over, and it was rather premature to criticise the Herts Council until the result of their efforts was developed in the course of a year or two.

Mr. Healey referred to the question of tarred macadam made with slag, and the fact that slag was a rather bad material to deal with in frosty weather. So far as he could gather of the patent system referred to, the slag was permeated with oil of tar when it was hot, and was thus rendered practically impervious to any moisture. If they could keep the moisture out of any material, the frost would have very little effect upon it.

With reference to the various sizes of the stones in a given gauge, he had shown the exact proportion of each size in a given instance before and after wear.

With regard to Mr. Benedict's remarks on the profile of the road, he agreed that the flatter the road, the better; but, the flatter the road the more smooth must the surface be to prevent any collection of moisture, and the more cleanly must the road be swept from mud. To maintain a true surface there was required quite a minimum of slope from side to side, because the principle of road making was, surely, to make the road so that the traffic could distribute itself from side to side. As he had pointed out in his paper, in a given instance, three-fifths of the whole traffic of the road went over the centre, and only one-fifth went down each side.

He was exceedingly obliged to the members for the very kind way in which they had received his paper, which it had been a pleasure to him to prepare.

May 4th, 1903.

J. PATTEN BARBER, President, in the Chair.

CERTAIN VEXATIOUS AND FALLACIOUS CEMENT TESTS NOW IN VOGUE.

By D. B. Butler, Vice-President.

Although the general quality of Portland cement has greatly improved, and become considerably more reliable during the past two or three decades, it is still a material which is far from absolute perfection. It is therefore necessary to apply certain tests, to determine its quality and to ascertain its suitability for the particular work in which it is intended to be employed. The object of testing cement is to determine as far as possible what results it may be expected to give in actual constructive work, and all tests which contribute to the user's knowledge of the material and to the best method of treatment, in order to obtain the most satisfactory results, are to be commended. Certain tests are however sometimes specified, the enforcement of which is vexatious to the manufacturer without any corresponding advantage to the user. Others, again, are specified which are not only vexatious and useless, but also utterly misleading, and while they are wholly fallacious as an indication of quality, needlessly vex and hamper the manufacturer.

Perhaps the most frequent cause of vexation and friction between manufacturer and user, is the want of uniformity in the methods of carrying out even the best known and most frequently used tests. Take, for instance, the simple test of fineness, which is ascertained by sifting a weighed quantity through a sieve having a certain number of holes per lineal inch and ascertaining the residue which will not pass. In the first place, there is no recognised standard as to the thickness of the wire of which the gauze of the sieve is composed, and secondly, there is no agreement as to how long the sifting shall be continued—both items of importance. It is evident that with a given number of holes per lineal inch, the thicker the wire the smaller the aperture through which the particles of cement have to pass, and therefore the greater the percentage of residue retained. But quite recently a case came under the author's notice in which the residue on a sieve having 80 holes per lineal inch—a very usual mesh—was in dispute. A sieve obtained from one of the recognised testing-sieve makers showed a residue of 3·6 per cent., whereas the sieve of another well-known maker gave a residue as high as 6 per cent. Each sieve was checked and found to have the correct number of holes, the difference being due simply to a difference in the thickness of the wire. Since the specification only allowed 5 per cent., it made all the difference between the acceptance and rejection of the consignment. The thickness of wire of the various testing-sieves adopted by the late Henry Faija and afterwards continued by the author was as follows:—

No. of Sieve.	New Standard Wire Gauge.	Thickness of Wire.	Width of Opening.
sieve		inch	inch
50 × 50	35	·0084	·0116
70 × 70	38	·006	·0083
76 × 76	39	·0052	·0079
80 × 80	39	·0052	·0073
100 × 100	41	·0044	·0056
120 × 120	43	·0036	·0047
180 × 180	45	·0028	·0028
200 × 200	46	·0024	·0026

On the Continent and in America the standard adopted, for the sake of uniformity, is that the thickness of the wire shall be one-half the size of the opening, i.e. in a sieve having 100 holes per lineal inch the size of the opening would be $\frac{2}{3}$ of $\frac{1}{100}$ = ·0066 inch, and the thickness of the wire of the gauze $\frac{1}{3}$ of $\frac{1}{100}$ = ·0033 inch. Being the only standard of the kind in existence, and in order to bring his results into line with Continental and American practice, the author has recently adopted this standard in his testing rooms. The following table gives the thickness of wire of the various sieves and the corresponding size of the aperture.

No. of Sieve.	New Standard Wire Gauge.	Thickness of Wire.	Width of Opening.
sieve		inch	inch
50 × 50	37	·0068	·0132
70 × 70	40	·0048	·0095
76 × 76	41	·0044	·0087
80 × 80	41½	·0042	·0083
100 × 100	44	·0032	·0067
120 × 120	45	·0028	·0055
180 × 180	47½	·0018	·0037
200 × 200	48	·0016	·0034

The matter of the length of time during which the sifting operation is prolonged, also has more effect on the result than is generally appreciated. The author's contention is that the sifting should be continued until practically nothing passes. Working either with 5 ounces or 100 grammes of cement, about five minutes' sifting will suffice. If, however, the sifting is continued even for an hour, minute quantities will still continue to pass the sieve as the following experiment will show. The sieve used was the No. 76 × 76, and the weight of cement taken 10 ounces.

	Per cent.
After 10 minutes' sifting the residue was	13·5
„ 20 „ „ „	13·0
„ 30 „ „ „	12·5
„ 40 „ „ „	12·1
„ 50 „ „ „	11·9
„ 60 „ „ „	11·7

The author's contention is that such unduly prolonged sifting does not actually show the fineness of the cement, but that many particles which are too large to pass the sieve during the first five minutes or so, are, by continual attrition one upon another during the prolonged operation, reduced sufficiently in diameter to just pass the sieve. And he is of opinion that if the sifting were prolonged for two or three hours, there would still be a weighable quantity passing through at the end of that period.

The most striking example of an absurdly misleading test is that known as the "marmalade pot" or temperature test, brought forward by Mr. G. F. Deacon some few years ago, and, with some modifications, since adopted by other engineers, who, if they were to give the matter a moment's consideration, would at once perceive the falsity of the inferences deduced.

In the course of a paper read before the Institution of Civil Engineers, 1896, on the Vyrnwy Water-works of the Liverpool Corporation, Mr. Deacon, the engineer of these works, advocated what he described as "a perfectly simple and exhaustive test for free lime which can be made in a few minutes, and which he has adopted ever since." It was as follows: "A hand sample of cement, a small vessel of water, a marmalade pot and a thermometer are left together for a short time to acquire a uniform temperature. The cement is then gauged in the pot as quickly as possible with just sufficient water to render it plastic, and the thermometer being immediately pressed into it the initial temperature is recorded. If within fifteen minutes the rise of the thermometer exceeds 2° Fahr., or within sixty minutes 3° Fahr., the cement is further exposed before use. No bin of cement was certified for use on the works until it had passed one of these tests." During the discussion which followed the reading of this paper, the author suggested that Mr. Deacon's reasoning was fallacious, and that the evolution of heat on adding water was due rather to the action of crystallisation, or setting of the cement, than to the heating of any free lime present. In support of his theory the author quoted some results taken from his predecessor's testing books of 1882, which went to show that cement which evolved heat to the extent of some 20° Fahr. during setting, and which therefore, according to Mr. Deacon's theory, should contain a highly dangerous amount of free lime, proved to be perfectly sound when tested in the ordinary way. This point was subsequently touched upon by the author in his paper on "The Finer Grinding of Portland Cement and the Comparative Value of the Coarser Particles," published by the Institution of Civil Engineers as a selected paper in 1898, from which the following extract may perhaps be permitted:—

"To ascertain the relation between the setting properties of cement and the heat evolved during setting, and also how far the theory was correct, that little or no increase in temperature pointed to the absence of 'free lime,' that is a 'sound cement'; the rise of temperature during setting of each sample in the Table was also noted, and in each case it was found to bear a distinct relation to the time occupied in setting."

"Each sample was also tested for soundness in the Faija apparatus, and the results recorded; it will be seen that cement L, in its original condition, was unsound, although it only showed an increase of 9° in sixty minutes; when extremely finely ground the heat evolved during setting was 29° in thirteen minutes, and the fine grinding had rendered it perfectly sound. The latter result was surprising, and efforts were thereupon made to procure one or two unsound cements, and ascertain the effect of grinding them extremely fine. Cement P was specially prepared for the author as an over-limed, unsound cement; when treated in the Faija apparatus it 'blew' badly, and disintegrated almost entirely, but after being ground extremely fine, this 'blowing' characteristic had practically disappeared. Cement Q, on the other hand, was a badly manufactured cement, being made from a very hard chalk, insufficiently reduced during the amalgamation of the raw materials. This sample also 'blew' very badly when treated in the Faija apparatus, but after being ground extremely fine, these indications disappeared entirely."

"To ascertain more conclusively whether the action of setting or the presence of 'free lime' was responsible for the rise in temperature noted, cements P and Q in their coarse condition

Cement.	How Treated.	Fineness—Residue per cent. on Sieves of Meshes per lineal inch.			Setting Properties.		Increase in Temperature during Setting.	Return to Normal Temperature.	Pat treated in Faija Apparatus for Soundness.
		180	76	50	Initial Set.	Set Hard.			
					minutes	mins.	° F. mins.	mins.	
J	As received from manufacturer	22·4	6·0	Nil	25	45	22 in 40	120	Sound
,,	Reground to pass 180 sieve	Trace	Nil	Nil	1	5	38 in 5	90	,,
K	As received	26·6	10·0	2·7	30	90	17 in 100	240	Sound
,,	Reground as above	Trace	Nil	Nil	6	15	32 in 11	150	,,
L	As received	24·4	7·6	1·5	30	120	9 in 60	180	Blown
,,	Reground as above	Trace	Nil	Nil	7	15	29 in 13	120	Sound
M	As received	30·0	6·7	1·2	20	60	21 in 34	150	Sound
,,	Reground as above	Trace	Nil	Nil	2	10	26 in 8	75	,,
N	As received	28·4	9·3	1·0	15	30	25 in 21	120	Sound
,,	Reground as above	0·6	Nil	Nil	1	10	32 in 4	120	,,
O	As received	26·4	7·7	0·5	Undefinable	360	2 in 39	160	Sound
,,	Reground as above	0·4	Nil	Nil	8	25	27 in 12	95	,,
P	As received	18·0	3·0	0·8	15	240	15 in 23	120	Badly blown*
,,	Reground as above	0·4	Nil	Nil	2	240	23 in 5	100	Very slightly blown *
,,	As received mixed with 2 per cent. gypsum	18·0	3·0	0·8	Undefinable	1440	1 in 15	35	Blown *
Q	As received	34·8	16·0	3·6	20	30	17 in 35	180	Badly blown
,,	Reground as above	1·6	Nil	Nil	2	5	26 in 5	180	Sound
,,	As received mixed with 2 per cent. gypsum	34·8	16·0	3·6	Undefinable	1440	1 in 15	30	Blown

* A specially prepared "over-limed" cement.

were mixed with 2 per cent. of gypsum, which, as is well known, retards the setting of cement; the result was that they were thus rendered extremely slow setting, and while still unsound, and giving decided indications of 'blowing' in the Faija apparatus, they showed an increase during setting of only 1°. As, therefore, the rise of temperature during setting depends upon the setting properties of the cement, and in no way determines the presence of 'free lime' or other disruptive agencies, the author is strongly of opinion that to enforce such a test, while it certainly ensures the delivery of a very slow setting cement—which in view of the method of working adopted by Mr. Deacon was absolutely imperative—in no way guards against an unsound cement, and imposes needless restrictions upon the manufacturer. Unsound, over-limed cements are generally slow-setting, and therefore evolve little or no heat during setting, while, on the other hand, a case lately came under the author's notice of a cement which withstood the severe hot-water test of Deval, and yet showed an increase of as much as 25°."

It was hoped that the foregoing would have been sufficient to demonstrate the absurdly misleading and untrustworthy nature of the temperature test, but the author regrets to find that it is still being enforced in a great many instances, and causing an immense amount of unnecessary trouble and friction. In one case a corporation engineer rejected several deliveries as unsound purely on account of evolution of heat, or rise of temperature during setting, involving the unhappy contractor in a law suit and the loss of several thousand pounds. In another instance the engineer committed himself to the statement in his specification, that a cement showing a rise of 6° Fahr. was not fit for use—a totally untenable proposition in the face of the experiments quoted in the foregoing, and hereafter set forth. In a third instance the specification stated that no cement would be further tested which showed a greater rise than 6° Fahr.—a similarly absurd statement. But the most flagrant instance of all was in a specification for cement for export to the Pacific coast, where the specification closely copied Mr. Deacon's method of carrying out the test and stated that "it will then show the rise in temperature caused by overliming."

Further examples of the absurdity of the temperature test have therefore been collected, as opportunity offered, from samples passing through the author's hands for testing and examination in the ordinary course of practice during the past few months. Fortunately for the user, cements containing free lime, or what are generally called unsound cements, are now comparatively rare, and therefore only a few examples of this kind are available. On the other hand, although only a few are quoted, examples of perfectly sound cements showing a considerable rise of temperature during setting could be multiplied indefinitely, in fact the author has had occasion to examine hundreds of samples in this way, and has never yet been able to establish the slightest relation between rise of temperature and soundness.

Table I.—Examples of Cement Evolving Considerable Heat during Setting, and yet Passing every known Test for Soundness.

Sample No.	Fineness.			Setting Properties.		Increase in Temperature during Setting.	Tests for Expansion, Contraction or Soundness.		
	100	76	50	Initial Set.	Final Set.	° F. in Mins.	Faija.	Deval.	Test-tube Test.
				mins.	mins.	° mins.			
I.	24·0	14·6	7·0	3	10	15 in 6	Sound	Sound	Sound
II.	..	4·0	..	5	15	17 in 4	„	„	„
III.	10	..	..	5	15	18 in 10	„	„	„
IV.	5·0	1·0	0·2	..	..	30 in 6	„	„	„

Table II.—Examples of Cements showing No Rise of Temperature, and yet utterly Unsound and Worthless.

Sample No.	Fineness.			Setting Properties.		Increase in Temperature during Setting.	Tests for Expansion, Contraction or Soundness.		
	100	76	50	Initial Set.	Final Set.	° F. in Mins.	Faija.	Deval.	Test-tube Test.
				mins.	hours.	° mins.			
V.	3·2	0·4	trace	30	6	1 in 12	Blown & disintegrated	Reduced to mud	Tube cracked in 3 days
VI.	19·8	10·0	3·0	40	..	1 in 10	Blown	Blown	Tube cracked
VII.	13·0	6·0	1·0	60	4	nil	„	Disintegrated	„
VIII.	19·2	10·0	2·0	45	5½	„	Badly Blown	„	„

Reproductions of photographs of pats of each of the above samples, after treatment in the Faija apparatus for soundness, are given in Figs. 1 to 8 in the sheet of illustrations. It will be observed that Nos. I. to IV., which, according to the temperature test should be unsound and unfit for use, are perfectly sound, without a sign of cracking anywhere; they also successfully withstood the more drastic treatment of the Deval hot-water bath. Nos. V. to VIII., on the other hand, which show no rise of temperature, and which would have been accepted as sound and fit for use under Mr. Deacon's specification, have practically disintegrated, and would be utterly worthless as a constructive material. In fact, their swelling and disintegration would cause them to be a destructive material, and would bring about the ruin of any building in which they might have been employed. It may be remarked that the briquettes of No. V. in ordinary cold water cracked and swelled to nearly double their proper size in less than a month, and subsequently disintegrated and fell to powder—facts which speak for themselves as to the futility of the temperature test.

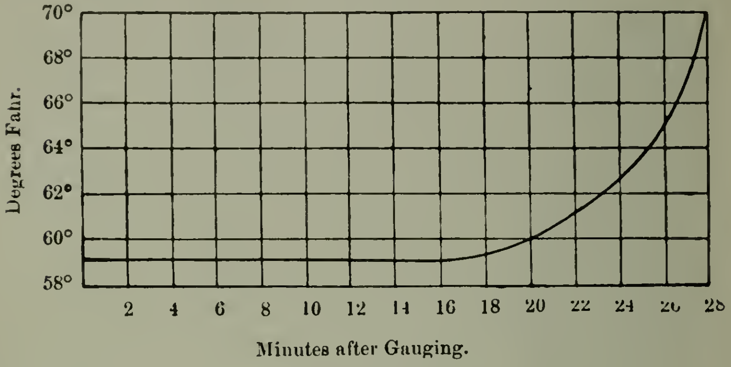
If a greased thermometer be inserted into a freshly gauged pat of cement, and the behaviour of the pat carefully noted, it will be observed that as soon as the mass begins to stiffen and lose its fluidity, the mercury will begin to rise, showing that crystallisation has commenced. If the hardening proceeds rapidly, the thermometer will show a corresponding rapid rise, while if hardening proceeds but slowly the thermometer will indicate the evolution of little or no heat. Broadly speaking, the explanation is this—when a cement sets quickly and crystallisation is rapid, the heat is evolved in a few minutes and the thermometer is correspondingly affected; while, on the other hand, if setting is slow, the same number of thermal units may be evolved, but they are spread over such a long period of time that they are lost by radiation and the thermometer is not appreciably affected.

The mere statement that a cement shows a rise of 15° or 20° during setting, really indicates nothing, except that at some period or other during setting the crystallisation was very rapid. It frequently happens that a cement does not commence to set until 15 or 20 minutes, or often longer, after the addition of water, and then the crystallisation proceeds at such a rapid rate that it is set hard within 15 or 20 minutes from the time that the hardening commenced. Four examples of this kind are given in the following table.

Table III.—Examples of Cement showing Considerable Rise in Temperature, and yet having a Sufficiently Slow Initial Set for all General Constructive Work.

Sample No.	Fineness.			Setting Properties.		Increase in Temperature during Setting.	Tests for Soundness.	
	100	76	50	Initial Set.	Final Set.		Faija.	Deval.
IX.	6 p.c.	1 p.c.	Trace	20 mins.	40 mins.	Rise in temperature 1 min. after gauging = 0° " " 5 " " = 0° " " 15 " " = 0° " " 18 " " = 0° " " 20 " " = 1° " " 25 " " = 6° " " 30 " " = 11°	Sound	Sound
X.	11 p.c.	3 p.c.	0·6 p.c.	20 mins.	45 mins.	Rise in temperature 1 min. after gauging = 0° " " 5 " " = 0° " " 15 " " = 0° " " 18 " " = 0° " " 20 " " = 1° " " 25 " " = 4° " " 28 " " = 11°	Sound	Sound
XI.	12 p.c.	1·8 p.c.	0·2 p.c.	12 mins.	30 mins.	Rise in temperature 1 min. after gauging = 0° " " 5 " " = 0° " " 10 " " = 1° " " 15 " " = 8° " " 20 " " = 13°	Sound	Sound
XII.	4·2 p.c.	..	..	10 mins.	35 mins.	Rise in temperature 1 min. after gauging = 0° " " 5 " " = 0° " " 10 " " = 1° " " 15 " " = 11° " " 20 " " = 17°	Sound	Sound

To make the matter perfectly clear a diagram of the temperature curve of sample No. X. is given below.



To assume therefore that because a cement shows a considerable rise of temperature it is conseqently too quick setting for ordinary use is altogether fallacious, because a cement which has an initial set of 10 or 15 minutes when gauged neat would have that time prolonged to at least 30 or 45 minutes when mixed with sand or aggregate, which is ample time in most classes of constructional work to allow of the concrete being got into position before setting commences. When once the concrete is in position and at rest, it surely cannot matter how soon or how rapidly the hardening proceeds; in fact, in many cases rapid hardening is an advantage, as it allows the work to be proceeded with more quickly than, for instance, if the subsequent induration were so slow as to prevent the centres being struck or more weight being placed upon the previously completed work than it would safely bear.

Since all bodies expand with heat and contract with cold, it may be urged that the evolution of considerable heat during setting gives rise to expansion of the concrete and thus endangers its stability. To make sure on this point it will be observed that all the cements herein enumerated were tested for expansion during setting by filling a test-tube with a portion of the gauged cement of which the pat tested for evolution of heat was composed. It is reasonable to assume that if any dangerous expansion took place during setting, the thin glass of which the test-tube was composed would be fractured; but in each case they remained intact without a sign of a crack anywhere.

It is therefore obvious that only an extremely slow setting cement will pass the "marmalade-pot" test, and the author has a shrewd suspicion that in the case of the Vyrnwy Water-works, and other places where the same conditions as to rise of temperature are insisted upon, the cement manufacturer attains the desired result by the simple expedient of adding a small percentage of gypsum, which it is well known retards the setting of cement but in no way counteracts the effect of any free lime that might be present. As a matter of fact, Mr. Deacon's "marmalade-pot test," as it has since been christened, is based upon entirely erroneous premises. Being a large user of lime, and knowing that the slaking or hydration of lime evolves heat, he appears to have jumped to the conclusion that any heat evolved by Portland cement upon the addition of water must be due to the slaking of the free lime contained in it. Portland cement, however, is an entirely different material; having been subjected to very much greater heat in the process of manufacture, the chemical constitution of its calcic compounds is consequently entirely different. Even assuming there was sufficient free lime in the cement to affect the thermometer on adding water, such lime would not be in the least dangerous. The very fact that it evolved heat showed that it had been slaked and rendered innocuous by the water used for gauging. As a matter of fact, it is the free lime which is confined within the coarser particles of the cement which constitutes the most dangerous and insidious forms of unsoundness or blowing, inasmuch as it is not attacked immediately on the addition of water, and therefore would not affect the thermometer in the least degree, but yet would cause internal disruption and disintegration at some future period—perhaps months afterwards.

It may be claimed that the rise of temperature during setting gives useful information as to the setting properties of the sample under examination, which it undoubtedly does, but at the same time the truer and more accurate method of determining setting is by the well-known and universally adopted pat test, in which the actual hardening of the cement is ascertained by the indentation of a weighted needle. It is a well-known fact that if cement is worked or manipulated after the period of initial set, i.e. after setting or hardening has commenced, its subsequent strength is correspondingly diminished. Now, by making a small pat, and noting when the mass loses its fluidity and is no longer totally mobile when touched with the finger, an accurate determination may be made as to how long it may be safely worked without detriment; whereas, when tested by the thermometer alone, it is not by any means easy to determine when the mass has reached the stage known as initial set, more especially with a moderately slow setting cement.

In view, therefore, of the facts and experiments briefly set forth in the foregoing, the author considers he is justified in asserting and maintaining with all possible emphasis that the determination of the evolution of heat during setting, so far from being "a perfectly simple and exhaustive test for free lime," is based on entirely false premises and is a vexatious and absurdly misleading test, serving no useful purpose whatever. He consequently urges upon engineers and cement-users in general the desirability, in the name of common sense, of its being immediately discarded wherever specified.

In conclusion, whilst recognising the fact that exceptional circumstances require exceptional qualities of cement, the author puts forward the following standard specification as one which would ensure the delivery of a good sound cement suitable for the requirements of general engineering constructional work. The fineness and tensile strain are a little more exacting than those mentioned in his standard specification published some four or five years ago; but at the same time he does not think that any first-class manufacturer would find the least difficulty in complying with it.

STANDARD SPECIFICATION FOR GENERAL PURPOSES.

The whole of the cement shall be pure Portland cement, and shall conform to the following tests:—

Fineness of Grinding.—To be such that when sifted through a standard sieve having 50 holes per lineal inch, there shall not be more than one-half (½ per cent.) by weight of residue; when sifted through a sieve having 76 holes per lineal inch, there shall not be more than five (5 per cent.) of residue; and when sifted through a sieve having 100 holes per lineal inch, there shall not be more than twelve (12 per cent.) of residue.

Time of Set.—A pat of neat cement gauged with the minimum of water at the normal temperature (60° Fahr.), and placed on a glass or other non-porous slab, shall not commence to set in less than eight minutes, or take longer than five hours to set hard.

Soundness, or Freedom from Expansion and Contraction.—A pat submitted to moist heat and warm water in the Faija apparatus for soundness at the usual temperatures, viz. 110° Fahr. and 120° Fahr. respectively, shall show no cracks or signs of expansion after 24 hours.

Tensile Strength.—Briquettes of neat cement, gauged with the minimum of water on a non-porous bed and placed in water 24 hours after gauging, shall carry an average tensile strain of not less than 350 lb. per square inch after three days, 450 lb. after seven days, and 550 lb. after 28 days, from the time of gauging.

Briquettes composed of three parts of standard sand to one part of cement, by weight, treated as above, shall carry an average tensile strain of not less than 150 lb. per square inch at seven days, and 250 lb. at 28 days, from the time of gauging; but no matter how much greater strength may be developed at the earlier dates, both neat and sand briquettes must develop an increase of at least 50 lb. between each date.

DISCUSSION.

The PRESIDENT moved a cordial vote of thanks to Mr. Butler for his paper.

The motion was carried by acclamation.

The following communications were then read by the SECRETARY, the respective writers being unable to be present at the meeting.

From Mr. WALTER J. COOPER, of the South Wales Portland Cement and Lime Company :—

Mr. Butler is taking up a subject which needs urgent and earnest attention on the part of cement manufacturers who are often much worried and hampered by absurd specifications, and by the ignorant reading of them. I have one case vividly in mind now, in which my company supplied cement for a waterworks contract. The cement was irreproachable in every respect, but unfortunately, as it set hard, neat, in about forty minutes, the rise of temperature was slightly more than the engineer approved. He refused to allow the use of the cement because the rise of temperature denoted, he said, a very excessive amount of lime. He evidently regarded these temperature tests as accurate and quick methods of quantitative analysis. Another cement was used, it gave an imperceptible rise of temperature and passed with flying colours. The tester showed me a few months afterwards the briquettes of the cement which he had kept on a shelf. They were very much swollen and were in every stage of disintegration. The lime present I ascertained to be about 64 per cent. as against 60 per cent. in the cement which was refused because it was too high limed. Such occurrences speak for themselves, and in my opinion it is high time a standard specification should be adopted, and that fanciful tests, too often based on utterly wrong ideas, should be suppressed.

From Mr. ARTHUR HARSTON, Architect, of 15 Leadenhall Street, London:—

Of late years there has been considerable commotion in the cement trade as to the addition of ragstone, slag, and more recently coke breeze, to the cement for the alleged purpose of improving its quality, although it is generally conceded by those best informed that those substances are merely adulterants to enable the vendor to sell some very cheap material at a very superior price, an inexpensive method of increasing the bulk at the cost of lowering the quality. Unfortunately, all these alterations in manufacture are made without any consultation with the users of the cement, and this remark applies equally to the foregoing as to what follows.

But now we have, during the past few years, another addition (which can scarcely be termed an adulterant) in the shape of sulphate of lime, or plaster of Paris. It is said that this is to meet the demand for a slow setting cement, and to prevent expansion and to obviate the time-consuming necessity of aerating the cement so as to air-slake any free lime it may contain. I would very much like to have (as I am sure your members would also) Mr. Butler's general views on this latest alteration, and in particular whether it is responsible for causing or delaying a slight expansion which it has lately been observed takes place in cement concrete floors at from six to eighteen months after the setting. It is noticed that this occurs quite irrespective of the season when the cement was used, some being in hot weather, other in cold, some in wet and other in dry. Sooner or later, from six to eighteen months, the expansion takes place and damages the brick walls. Years ago if expansion occurred it came at, or soon after, the setting. Now it appears that the evil day is only deferred until the builder and cement merchant are paid, and it does not trouble them much.

From Mr. GEORGE F. DEACON, of 16 Great George Street, Westminster:—

Mr. Butler's paper contains much information with which I concur, for example: if any engineer specifies a test for fineness based merely upon the number of meshes to the inch, it is perfectly clear that he has only himself to blame if the intention is misunderstood and leads to controversy. The weight of the mesh per unit of area, or some such alternative as Mr. Butler suggests, is absolutely necessary to make the specification for fineness conclusive. I also agree with him in fixing a limit to the time of sieving.

I have, however, to take exception to the use of such terms as "an absurdly misleading test," "absurdly misleading and untrustworthy," "a similarly absurd statement," and "absurdity of the temperature test," which occur in many parts of the paper, when applied to a matter about which the author is under a complete misapprehension. The test for soundness by the rise of temperature during the process of setting is certainly not a conclusive test if taken alone, but it is an exceedingly useful and readily applied test upon works, for the purpose of determining whether cement, which is otherwise satisfactory, has reached, if it ever does reach, the condition which I desire that it shall possess before being used. The author seems to assume that I have applied such a test for the purpose of determining whether cement, on receipt from the manufacturer, shall or shall not be there and then rejected. This is a complete misapprehension. The test has never with my sanction been used in such a manner. On the contrary I have been most careful to warn contractors that they must not expect to hold their manufacturers to any test, based upon this principle, for the soundness of cement before or at the time of delivery, and have always pointed out that, if the cement is slow setting, is ground to the specified fineness, is sound and is of the prescribed strength, it can by aeration be brought to stand the temperature test, after which it will be suitable for use in the work. It is perfectly easy to obtain cement which would not, for example, pass the test for tensile strength, but which would pass the temperature test, and would subsequently break up in the manner shown in the author's photographs. But as a matter of fact, though the temperature test has been in successful use upon works for at least a quarter of a century, I have never known or heard of a single case in which it has been applied with disappointing results. There may be cases in which this test has been applied, and other necessary tests omitted with disastrous results, but such cases have not come to my knowledge.

In the year 1896, when my paper on the Vyrnwy works, mentioned by the author, came before the Institution of Civil Engineers, I had used this test for fifteen years, but was not then aware that the late Mr. Henry Law had used the same test for a much longer time with the same excellent results. He told me of it afterwards and showed me his specifications. Those who knew Mr. Law and his works will I think agree with me that he understood Portland cement.

I am not concerned in this communication to enter into any controversy as to whether the cause of rise of temperature in conducting such a test is wholly or partially due to the energy of setting as distinguished from the presence of free lime. I agree with the author that the specification of fineness goes very far to remove the danger from free lime, and as a matter of fact I always prescribe fine grinding.

It is certain that Mr. Law, or someone, long ago devised a test which is exceedingly simple, and which may be applied with the greatest confidence to determine the period of aeration necessary to bring a cement of proper quality into what I regard as a suitable condition for use in the works to which I apply it. Until an equally simple and trustworthy test for this purpose is communicated to me I shall continue to use it.

Mr. Howard Humphreys said, that the subject of the paper was one upon which he had spent a considerable amount of time during the last fifteen years, for like Mr. Butler, he was largely occupied in testing work; but he regretted to say that he was very distinctly at issue with Mr. Butler in some of his conclusions, though he was in agreement with many of his propositions.

With regard to the standardisation of tests, he felt that they should do in this country what had been done very largely in Germany, France, the United States and even some of the colonies. That was to say, engineers should put their heads together and endeavour to arrive at some sort of agreement as to specification, for, at the present time, the methods of testing were absolutely chaotic and sometimes monstrously ridiculous.

He agreed that the fineness of the sieve wire should be settled. It had been fixed in many countries, but in England there was no agreement. The result was that different engineers got widely divergent results with regard to residues.

He had hoped that Mr. Butler would have dealt with the fallaciousness of the seven days' neat tensile test, for if ever there was a misleading test concocted by muddle-headed men it was that one.

With regard to the evolution of heat, he really thought that Mr. Butler had belaboured Mr. Deacon rather unnecessarily, and he appeared to have read into Mr. Deacon's remarks a meaning which Mr. Deacon never intended. He did not think that Mr. Deacon attached as much importance to the "marmalade pot test" as Mr. Butler seemed to think. His (the speaker's) impression was that Mr. Deacon merely used that test to indicate when a cement could be used on work without danger of subsequent expansion. In very many cases cement which came into the laboratory showed signs of expansion upon its arrival, and under the boiling test showed definite radial cracks, but upon cooling was as sound as it could be under the same test. He had not yet found that crystallisation tended to cause radial cracks. He believed that lime, either free or loosely combined, was very largely responsible for the cracking. He did not say that because there was not a rise in the temperature of a cement it was of necessity sound; and on the other hand it must not be taken that because a cement expanded when it came to the laboratory hot, it would also be unsound when it had cooled down. He thought Mr. Butler would admit that there was a certain amount of uncombined lime in every cement.

At the end of Mr. Butler's admirable work on cement, the question of lime in cement used upon sea work was dealt with, and Mr. Butler in quoting Dr. Michaelis on this point did not seem to doubt the statement that there was free lime. Would Mr. Butler tell them that the slaking of that free or partially combined lime did not cause a rise in temperature? Perhaps the real truth was that the rise of temperature was caused partly by the free lime and partly by crystallisation. He demurred entirely to Mr. Butler's view, that crystallisation was the sole cause of the evolution of heat.

A well-known American expert, Professor Woodall, said that his practice was to mix one ounce of water with five ounces of cement, and that the greater the rise in temperature of the mixture the greater the probability of there being too much free lime in the cement.

What was the true use of Mr. Deacon's test? There were certain cements which varied enormously under different conditions as to the heat evolved. Mr. Butler could tell them from his own book that the specific gravity varied with the age of the cement and the degree of hydration which had gone on. The strength of the briquette would also vary according to the age of the cement. It seemed to him (the speaker) that engineers should specifiy that a cement prior to use should evolve only six degrees of heat in one hour after mixing with a certain quantity of water, and that all tests should be performed after that degree of coolness had been attained, so that one batch of cement tests could be compared with another batch. In his own laboratory that practice was invariably followed. All cements were cooled down to six degrees and he thus made his tests at a time when the cement was fit to be actually put into work. That was fair both to the maker and to the consumer. But it was not fair to take a new cement and perform a series of tests upon that. Cement would frequently expand when it came into the laboratory new; whereas if it was brought into the condition in which it would be used upon works, no expansion would take place. There must be at all events some sort of idea of fairness to the maker.

Mr. Bertram Blount said, that he agreed with Mr. Butler that the rise of temperature test for Portland cement rested on a fallacy. It had come into existence by a false analogy between the behaviour of lime as such, and that of the lime in Portland cement. The argument took the form of saying that because certain hydraulic materials, e.g. hydraulic limes, contained free lime and gave a rise of temperature when mixed with water, therefore any hydraulic material which gave a rise of temperature when treated with water must contain free lime. Such a proposition was logically untenable and moreover was contrary to chemical knowledge.

Passing to the positive as distinguished from the destructive elements in the paper, he felt that they owed the author a debt of gratitude for striving to put their chaotic sieves upon a proper basis. There was no doubt that the absence of any fixed relation between the size of the wires and the size of the meshes was a cause of annoyance and dispute. If an authoritative committee could arrive at some definite standard, a very useful piece of work would be done and disputes, as little real as those of classic story with regard to the colour of the chameleon, would be done away with altogether. There were always plenty of subjects for differences of opinion and for dispute, and those which arose from a want of identity of premises were always to be deplored.

He observed by the way that in the proposed new standard for the size of the openings of sieves, the width of the openings was increased in almost every case. In preparing specifications they must of course be careful to take account of that fact, and when the openings were larger, they must stiffen the specification a little.

A great deal of the paper dealt with the formal refutation of the Deacon test, but he did not think that any person acquainted with the chemistry of cement would need conviction on that point. That method or pseudo-method of determining free lime in cement was not the only fallacious method which had been put forward for that end. And here he must make a confession on behalf of his own profession. There were a great many chemists, some of them more or less eminent, who had put forward methods for determining free lime in cement which depended upon some selective solvent action of a variety of solvents upon the cementitious constituents in ordinary cement. They used sometimes glycerine, and sometimes sugar solution, and they wrote long papers about them in polyglot periodicals. And when they had done all this and published elaborate tables, the fact remained that in a properly burnt Portland cement there was no free lime. If in a properly burnt Portland cement there was free lime, all chemists would welcome a method for extracting and determining it. He had himself sought diligently, but without success, to devise a method of that kind, and he would welcome any more successful attempt. The methods which had been put forward were based upon a lack of appreciation of the great difficulty of arriving at what was desired.

The standard specification put forward at the end of Mr. Butler's paper was a model in one respect, namely, its conspicuous brevity and directness. The ordinary cement specification was a terribly long document with a number of clauses and sub-clauses, some of which were mutually contradictory. The standard specification proposed in the paper was entirely intelligible, and, whether one agreed with it or not, there was no doubt as to its meaning.

As to the first clause, that relating to fineness of grinding, he thought that those who had studied the importance of grinding machinery in modern cement works would agree that the suggested residue, namely, 5 per cent. on a 76 × 76 sieve, was not too exacting. On looking through a number of tests which had been made of the cement of well known manufacturers, he found that with very few exceptions they passed triumphantly this somewhat exacting condition which ten years ago would have been thought almost impracticable. As to the importation of another sieve which was not very much finer, he had a slight doubt. He should have preferred to pass to something very fine, say, a 200 × 200 mesh sieve.

The time of setting scarcely called for comment; but the question of soundness did. The author's predecessor, Mr. Faija, substantially benefited cement manufacturers and engineers when he devised the test bearing his name. That was a useful test and one which could be readily applied. The question now arose whether the test which had served so long could be replaced by something better. The subject was under consideration by a committee appointed by the society for testing materials; and it had fallen to his (the speaker's) lot as chairman of that committee to try to devise some test which should have the advantages of practicability and of satisfactory and simple working which the Faija test possessed and which yet should be quantitative. The matter was not easy and the selection between the different tests was a matter much debated. He should urge that the acceptance of a standard specification be deferred until the committee had arrived at some conclusion.

As to tensile strength, it appeared to him that the importation of the sand test, which at one time was a very Cinderella among mechanical tests, was a perfectly sound and satisfactory course, and it was quite possible that in a short time the strength set down in the suggested specification would be thought to be too moderate.

Mr. Herbert E. Brooks said, that as a cement manufacturer he thanked Mr. Butler for the excellent paper which he had read. Though the experts disagreed on some points, there had been agreement upon one, and that was that cement was often unjustly condemned. With regard to the main question of rise of temperature, he and his colleagues could speak very feelingly, for they had often had difficulty upon that very point. The paper and the remarks which had been made by Mr. Blount entirely bore out the view which they had held for a long time upon that question. Their point of view, as that of cement manufacturers, was naturally held to be prejudiced, but the evidence which had been brought forward that night strengthened their position.

Allusion had been made to the very great increase in the fineness of grinding which characterised the cement industry of to-day. That was perhaps the most notable feature in connection with the manufacture which had arisen of late years. Increased fineness materially strengthened cement when used with an aggregate. An enormous difference was made in the results obtained from the same sample, if one part were ground to a greater degree of fineness than the other. And with the greater degree of fineness there came a greatly accelerated rapidity in setting. He did not pretend to be a chemist, but he thought that that bore out the view which they held that the rise in temperature was largely due to the process of crystallisation, which was a combination between the cement and the water and which could go forward more rapidly when the cement was reduced to a greater degree of fineness. The rise occurred during the setting process. The temperature test, as Mr. Humphreys had pointed out, might have some advantages, but if it could be shown to be misleading, their request that it should be abolished ought to be listened to. It had undoubtedly led to the unjust condemnation of first class cement, and that was a matter which ultimately had to be paid for by the consumer, because the manufacturer must make sufficient profit on his trade to cover losses of that character.

He was glad to say that engineers had assisted manufacturers in many cases, especially in connection with important contracts, by allowing tests to be made at works before delivery. He would ask those present to picture to their minds the position in which a manufacturer found himself when asked to tender on some of the specifications put before him which often contained clauses of a self-contradictory character, and sometimes also a clause saying, "If, in this or in any other respect, the cement shall not be satisfactory to the engineer-in-charge, it shall be forthwith rejected and removed from the works at the expense of the contractor." He had seen many colonial government specifications of that sort, and contractors were expected to send cement half round the world, and to go to an expense in the way of delivery which might be fully equal to the cost of the cement itself, and then to find themselves absolutely at the mercy of an engineer with unlimited discretion. The cement manufacturer had to provide for such cases in the prices which he asked. That was a sufficient illustration of the necessity of arriving at some standard specification.

He would venture to suggest that possibly many of the contradictory clauses in specifications existed to-day because so many engineers and architects used their specifications for show and refrained from enforcing many of the clauses. If they did seek to enforce all the clauses they would at once discover that some could never be complied with. He would suggest that engineers should give a little careful study to the clauses of their specifications, and they might rest assured that if they asked anything which would have the result of improving the article, manufacturers would give it their earnest and careful attention and support.

Mr. E. J. Silcock said, that the remarks which had been made hitherto appeared to lie between the experts and the manufacturers. Perhaps he might be allowed to say a word as a user of cement. He cordially agreed with both the experts and the manufacturers in the opinion that it was highly desirable that a satisfactory standard specification should be arrived at. The users of cement were between those two sets of gentlemen, and their difficulty was that when they got together they did not agree among themselves.

He had been very much interested in the remarks which had been made about the "marmalade pot test," because when it was first brought forward by Mr. Deacon he (Mr. Silcock) in common with many others was very much taken with that test. It seemed to him that it was a practical test which they could carry out quickly, and by which they could really ascertain whether the cement they were using was overlimed or not sufficiently cooled. He at once adopted the clause in his specifications, but he was afraid that he must plead guilty to the laxity complained of by Mr. Brooks, and that the clause was never enforced. He had carried out a great number of experiments and he had found that in almost every case the rise of temperature in the cement was more than the limit allowed in the specification; but he had never had the courage to condemn the cement because the temperature rose too much, the reason being that he found that although the temperature rose, the cement was giving satisfactory results, and he had long since given up the use of the clause in his specifications.

To give an idea of the difference between the experts and the manufacturers he might refer to a paper which was read by Mr. Bamber, who was a manufacturer, at Norwich, some years ago at a meeting of the Municipal Engineers. As far as he remembered, Mr. Bamber gave a model specification which had three requirements. First of all the amount of lime was to be within certain limits. He (Mr. Silcock) believed that it was to be within 60 and 62 per cent. The second test related to the degree of fineness, and the third test was the specific gravity. Mr. Bamber gave limits for all those three qualities, and some of the experts present on the occasion approved of the specification, but now we had an expert bringing forward an entirely different specification. He should like Mr. Butler to explain how it was that he and the manufacturers differed.

Mr. T. H. YABBICOM said, that he was glad to have had the opportunity of hearing a very interesting paper. Although he had been a user of cement for the last thirty years he found that his education in the matter was very deficient and that he had still a great deal to learn. The only point which he would touch upon was the tensile strain test. He had found in practice that the cement which would give a very high tensile strain was not by any means always the best that could be used in construction. He had in his mind a cement which gave a tensile strain of over 600 lbs. to the square inch at the end of fourteen days and that cement was accepted, but it proved an utter failure in work in consequence of "blowing."

Mr. GILBERT R. REDGRAVE said: With respect to the size of the wires and of the meshes of the sieves to be used, he thought that they would all agree that it was very necessary that they should have a standard, for it was quite evident that if the wires varied in different sieves they would get very discordant results from the test. He did not quite agree with Mr. Butler in his proposed standard specification, based on the sieve-test. Of course, all cement-users were aware that practically no particle of cement, which was retained on a one hundred mesh sieve (100 by 100 per square inch), was of any value whatever. The question was—what degree of fineness could the manufacturer give to the user, if the user was willing to pay for it? Every cement-user must buy his cement with some proportion of material in it which was useless to him. A manufacturer could make a cement which would practically all go through a hundred mesh sieve. If the cement-user was willing to pay the price needed to accomplish that, he could get a material which would be relatively of more value to him than one at a less price, which would leave 10 or 12 per cent. of residue on a hundred mesh sieve. But of course, in actual practice, it might be said that it was impossible to maintain throughout a long series of deliveries such a degree of fineness as that implied. Mr. Blount had, however, told them they could get something very nearly approximate to it, and if they could name, in the proposed standard specification, a sieve through which practically all the cement would pass, that would be the thing to aim at.

With regard to the question of the Deacon test, they were, perhaps, a little wrong in respect of the reason of the rise in temperature. The most recent theory of Portland cement chemistry was that all the lime present was combined, either with silica or with alumina. Of course, in an imperfectly made cement there might be small quantities of free lime which were bottled up, or surrounded with fused silicate, and which could not really become acted upon by the water till very much later, and such free lime might ultimately damage the work. But a perfectly made Portland cement, leaving the small proportion of iron, etc., out of consideration, was a mixture of tri-calcic silicate and tri-calcic aluminate, that was to say, a mixture with three equivalents of lime to each equivalent of alumina, and three equivalents of lime to each equivalent of silica. When a perfectly ground Portland cement was mixed with water, in the first instance the aluminate of lime became hydrated and they then got what was called the initial set. The hydration being a chemical action it necessarily caused a rise in temperature, and that rise took place almost immediately the water came into contact with the cement. The more finely the cement was ground, the more quickly the hydration of the aluminate of lime took place.

Then came the question of the silicate of lime. Now what occurred when a tri-calcic silicate was mixed with water was this; two equivalents of lime were set free and became converted into hydrate of lime, thus giving rise to the formation of those needle-shaped crystals which, under the microscope, were found abundantly present in all samples of Portland cement. Then there remained only a mono-silicate of lime, and the gradual elimination of that compound was what effected the final induration of the cement. The crystallisation, or the combination of the mono-silicate of lime with water, proceeded very slowly, and constituted the real so-called "setting" of the Portland cement. The hydration of the aluminate of lime which took place directly the water was added might occupy only a few minutes, about five minutes at the outside; but the action might be greatly prolonged from various causes. There were certain ingredients in Portland cement which hindered the action of the hydration of the calcic aluminate, but that heating, of which Mr. Butler had spoken, was most probably due to the immediate hydration of the aluminate of lime, and to the consequent chemical action.

As to the quantity of free lime present in Portland cement, Mr. Blount had told them that he thought that they might disregard it altogether and they might assume that there was practically none. They had in fact to deal only with the aluminate of lime and the silicate of lime, and not with free lime. He thought that what he had thus put before them was the true chemistry of Portland cement.

The sand test seemed to him to be the real test which the maker and the user should rely upon. Well-made Portland cement, which would carry 8 or 10 parts of sand, or whatever the quantity might be which was finally decided upon for testing purposes, was the cement which they all wanted; not a cement which in 3 or in 7 or 28 days would, when used alone, attain to great hardness. The neat test was not, he believed, a true test of the value of the cement.

Mr. H. H. Slater said, that as a cement maker, he only wished to say that he wholly agreed with Mr. Butler in all that he had said with regard to the temperature test. He thought that it was entirely misleading and that it should be abolished.

Mr. E. P. Wells said, that with regard to the temperature test he at first thought that there was something in it that required investigation, but after a few years he gave it up as an absolutely fallacious one. His reason for doing so was, that in September 1900 he went to Germany to inspect some concrete bridges in course of construction, and he noticed that the cement which was used there gave a rise in temperature, when the concrete was made in the proportion of 7½ to 1, of 40° Fahr., twenty-four hours after it was made. He asked the engineers whether they could account for this enormous rise in temperature, but they could not give a satisfactory answer. He thought at the time that there must be a very large amount of free lime present, and that that was the cause of the enormous rise and that the concrete would show signs of blowing after it had been made for some time, but he had found that that was not the case. He could not find in any cases that there was any fault whatever with the concrete, some of that which he inspected having been made seven years previously. There was not a single crack or sign of blowing. When he came back to England he obtained from Stuttgart 4 cwt. of cement which had been made in July 1900. He received it in 1901, and examined it on account of the rise of temperature that took place; his observations extended over a period of twelve months. The following were the results:—

Residue 58·75 per cent.; flour 41·25 per cent. as ascertained by passing the cement through Goreham's flourometer working with an air pressure equal to a 3-inch head of water. Residue 17½ per cent. on a 180 × 180 sieve. Rise of temperature 6 degrees in thirty minutes. Time setting, neat 8 hours; sand, 7 hours.

The average 7 days' neat tests gave 738, and the 28 days 725 lb. per sq. inch. The 3 to 1 sands 7 days old averaged 332, and the 28 day tests 442 lb. to the sq. inch. The neat 24 hours' test averaged 305 lb., and the 3 to 1 sands, 170 lb. to the sq. inch of sectional area.

The 4 to 1 Portland stone concrete tests gave the following crushing in tons per sq. feet:—

7	days old,	207	tons per	square foot.
28	„	269½	„	„
65	„	360¾	„	„

When made into concrete the strength being 5 to 1, the following were the results:—

3	months old,	282	tons per	square foot.
6	„	221	„	„
9	„	215	„	„
12	„	231	„	„

6 to 1 concrete:—

3	months old,	171	tons per	square foot.
6	„	156	„	„
9	„	151	„	„
12	„	197	„	„

7 to 1 concrete:—

3	months old,	134	tons per	square foot.
6	„	126	„	„
9	„	131	„	„
12	„	186	„	„

8 to 1 concrete:—

3	months old,	100	tons per	square foot.
6	„	157	„	„
9	„	122	„	„
12	„	131	„	„

9 to 1 concrete:—

3	months old,	93	tons per	square foot.
6	„	104	„	„
9	„	109	„	„
12	„	130	„	„

10 to 1 concrete:—

3	months old,	104	tons per	square foot.
6	„	116	„	„
9	„	97	„	„
12	„	145	„	„

It would be observed from the foregoing experiments that the results were not as satisfactory as could be wished, as the variations were erratic, alternately rising and falling, which was not a satisfactory feature, but it would be observed that the concrete, except in the case of the 5 to 1, recovered its strength at the end of 12 months, and would after then no doubt go on increasing in strength until the maximum was attained, which would be in about 4 years.

An analysis of the cement was made 12 months after it had been manufactured at Blaubeuren in Württemberg, with the following result:—

Water and carbonic acid	2·18
Insoluble residue	·81
Silica	19·10
Alumina	8·70
Oxide of iron	3·19
Lime	61·97*
Magnesia	1·45
Sulphuric anhydride	1·37
Alkali and losses	1·23

That cement did not show any sign of free lime being present. The analysts found that there was no fault to be found with the cement as it stood all known tests for soundness, and he could not understand the reason why there was that abnormal rise of temperature. He (Mr. Wells) wrote to the manufacturers asking whether they could account for the abnormal rise in temperature, and after two years they replied that " Portland cement during the process of induration always got heated. In the so-called box test their Portland cement increased by 1·5 to 2° C., and when mixed in large quantities the rise in temperature amounts to as much as 13° to 54° C. or an average of 74° F. The more extensive and the more compact the body of mortar was, the more the temperature was raised. When the cement had been kept for a long time, then it was found that the rise in temperature amounted to 31° C. or 56° F."

He made large masses of concrete with that cement in the proportion of 5 to 1. There was a considerable degree of heat evolved for over three days from the time of making, but after two years he had not found a sign of a crack or blowing. The abnormal rise of temperature in the German cement made at Blaubeuren he could only account for by the cement being made from a natural stone. That fact was not disclosed in the chemical analysis, which it would be observed was identical with a good English cement made from chalk and Medway clay and free from adulteration.

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* The lime contents when freshly made would be 63·30 per cent.

Mr. H. K. G. Bamber said, that the remarks he might have made from a chemical point of view had been already made by Mr. Redgrave, and what he would have said from a commercial point of view had been said by Mr. Herbert Brooks. He was glad that Mr. Butler advocated uniform mesh of sieve; he said that from the manufacturers' point of view. He thought that it would be well if Germans and Americans used the same test. If they compelled English manufacturers to use a particular sieve they should see that those at the other end of the world competing with English manufacturers were also using the same.

Mr. D. B. Butler, in reply, said that it had been the very greatest pleasure to him to listen to the remarks which had been made on the paper. Mr. Humphreys expressed the opinion that he (Mr. Butler) had been a little unnecessarily severe in his strictures of Mr. Deacon's temperature test. He was open to confess that he felt strongly and therefore expressed himself rather strongly in the matter, but at the same time he was sure that if Mr. Humphreys had been in his (Mr. Butler's) position, and had seen the amount of vexation and expense which had been caused to contractors and to users of cement by the enforcement of the clause to which he had referred, Mr. Humphreys would not have considered his remarks one whit too strong. Over and over again cases had been brought before him in which cement had been rejected on the rise of temperature alone, which of course was absurd.

Mr. Deacon in his letter took exception to the author describing the temperature test as an absurdly misleading test, etc., etc., and stated that the author was under a complete misapprehension in the matter. Unfortunately many engineers in common with the author, took Mr. Deacon to mean what he said when he described it in the paper referred to in 1896 as a "perfectly simple and exhaustive test for free lime which he had adopted ever since," the result being that many cement users, trusting to Mr. Deacon's reputation as a user of concrete, had embodied a similar clause in their specifications, as a definite and finally controlling test for free lime, and thus caused the needless vexation referred to.

Mr. Humphreys suggested that Mr. Deacon's use of the temperature test was to ascertain when the cement could be used on work without subsequent expansion, but that was just where it failed, as shown by his (Mr. Butler's) experiments. Mr. Humphreys' reference to the free lime mentioned by Dr. Michaelis suggested that he scarcely appreciated the chemical aspect of the question. Dr. Michaelis, in the paper in question, referred to calcium hydrate set free by the decomposition of the calcic constituents of every cement on adding water, which had nothing whatever to do with the matter under discussion, i.e. dangerous free lime in the dry cement powder. He (Mr. Butler) quite failed to see the utility of Mr. Humphreys' suggestion of cooling down to 6° rise of temperature before a cement was either tested or used. The only indication it could possibly give was the setting property of the cement, which, as stated in the paper, could be more reliably and practically ascertained by making a small pat and noting the rapidity of hardening. It really indicated nothing of importance, and in very many cases would involve cements, which were perfectly fit for use, being aerated for an unduly prolonged period, with consequent unnecessary expense.

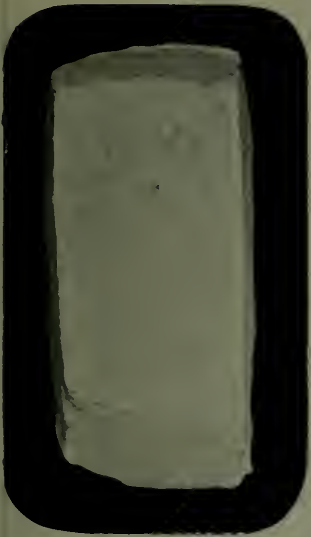
He was very pleased to find that Mr. Blount was in such complete accord with him as to the fallacy of the temperature test, and also endorsed his opinion that it was based upon fallacious premises, altogether contrary to chemical knowledge. Such testimony from one so thoroughly acquainted with the chemistry of cement was, he hoped, sufficient to prove his contention to the hilt. With regard to the sieves mentioned in the specification, there was a good deal in Mr. Blount's suggestion that a finer sieve than No. 100 should be included. In many instances the author used a 200-mesh sieve in his laboratory, but as it was not a sieve in general use, he had not included it in his specification.

Mr. Silcock's remarks amply bore out what he (Mr. Butler) had said as to other engineers trusting to Mr. Deacon's repute as a large cement user, and copying his temperature test for free lime, and also bore valuable testimony as to its causing the rejection of cement which would give perfectly satisfactory results in practice.

Mr. Wells had brought forward some very interesting results and on the whole supported the views put forward in the paper. The heat evolved, however, was very much in excess of what he (Mr. Butler) had ever experienced and he was a little at a loss to account for it. The experiments put forward by Mr. Wells as to the results of fine grinding traversed very much the same ground as that of the author's paper on the same subject published by the Institution of Civil Engineers in 1898.

In conclusion, he thanked the meeting for the kindly reception which had been accorded him, and he trusted that the discussion which had taken place would lead to increased knowledge of the properties of cement, and last but not least, to the abolition of the temperature test.

OUS CEMENT TESTS NOW IN VOGUE. D. B. BUTLER.



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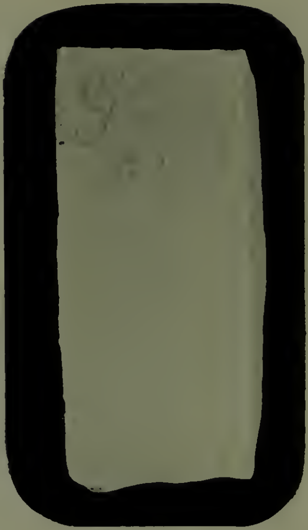
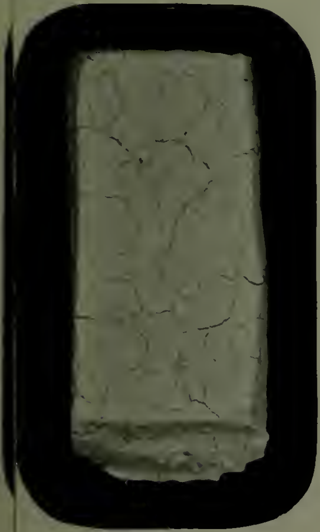


IV.

ND YET HAVE PASSED EVERY KNOWN TEST FOR SOUNDNESS.



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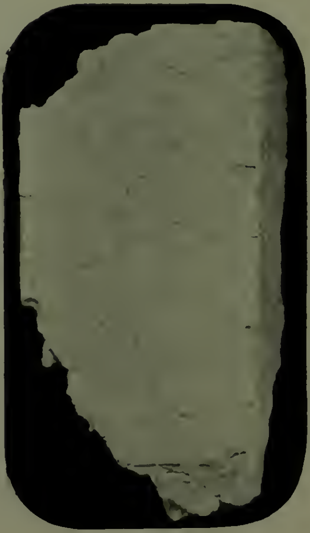
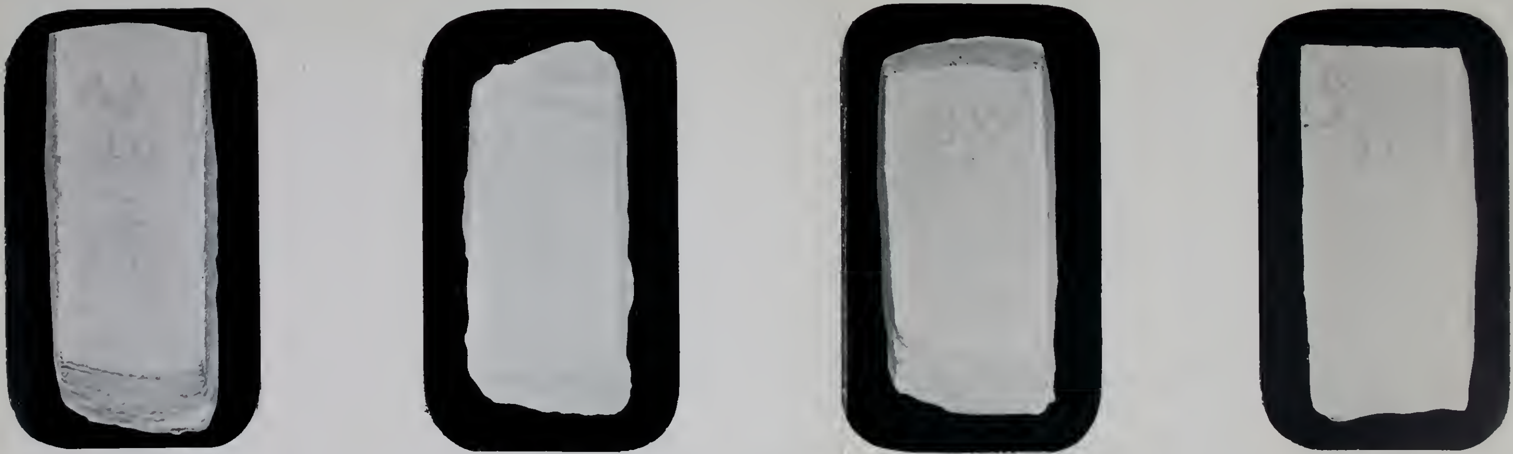


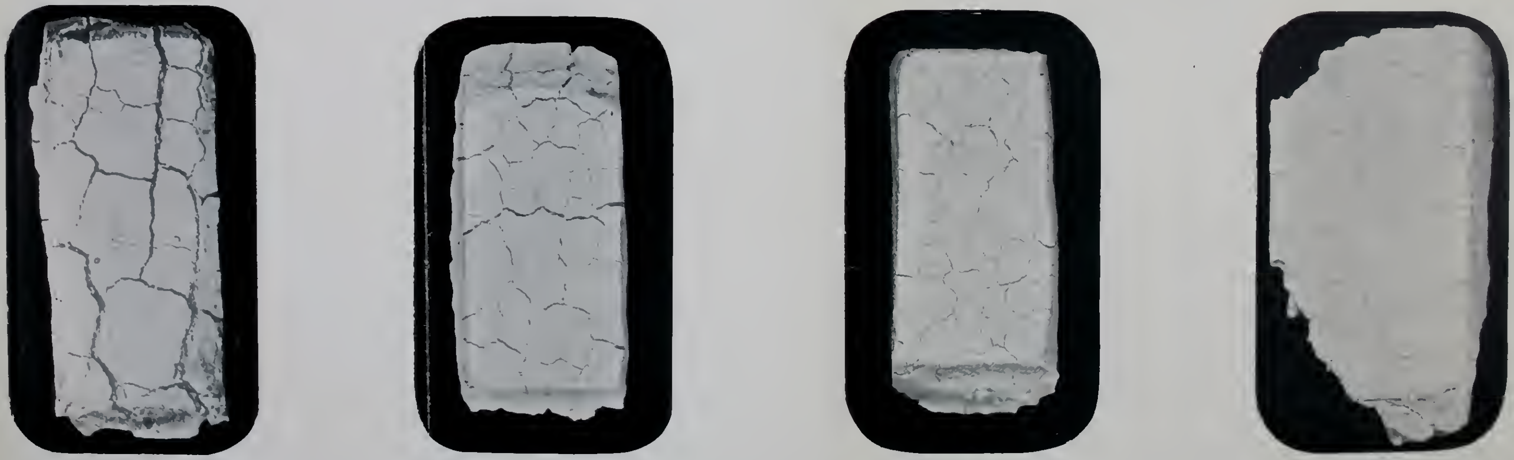
VIII.

ND YET ARE UTTERLY UNSOUND AND WORTHLESS.



I. II. III. IV.

Pats of Cements which evolved Considerable Heat during Setting, and yet have passed every known test for soundness.
(See Table I.)



V. VI. VII. VIII.

Pats of Cements which evolved No Heat during Setting, and yet are utterly unsound and worthless.
(See Table II.)

June 8th, 1903.

J. PATTEN BARBER, PRESIDENT, IN THE CHAIR.

ELECTRIC LIGHT STATIONS, THEIR DESIGN AND ARRANGEMENT.

BY ERNEST R. MATTHEWS.

DURING recent years the supply of electricity for light has become one of the chief municipal industries in this country. Little progress seems to have really been made until the year 1882, when the wonderful development of electricity both for light and power in America attracted the notice of Parliament, with the result that the Board of Trade were convinced that electricity for lighting purposes had a future before it, and so that Local Authorities should not be handicapped, an Act was passed in 1882 limiting private enterprise to seven years. No sooner was this Act in force than there was at once, in 1883, a great demand for provisional orders—69 were confirmed by Parliament in that year. Companies were floated in great numbers; but private enterprise very soon discovered what was involved in that clause in the Act to the effect that the local authorities could at the end of 21 years step in and acquire the undertaking at its then value; buildings, plant, machinery, and everything, without paying one penny for the goodwill, or compulsory purchase, or anything beyond the net cost, less depreciation. It was seen that under this clause the risk was too great, the result being appeals to the Board of Trade, and the outcome was that a committee was formed to draw up an amended Act. This, however, took time, and it was not until June 1888, that the Amended Electric Lighting Act was passed. During four years —from 1884 to 1888—only one provisional order was granted, and many companies failed.

The Amended Act assisted companies, in that it extended their life from 21 to 42 years, the local authority after this time had expired having the option of purchasing at the end of every 10 years. It has always been the intention of the Board of

Trade to give local authorities full scope, and to assist them as far as possible in forestalling private companies. But the local authority has its responsibility in the matter, for unless a provisional order is acted upon within two years it lapses and has to be renewed, and this cannot be done unless the local authority can give evidence to the Board of Trade that it is pushing on with the undertaking.

From 1888 to 1901, under the Amended Act, rapid progress was made, and the author finds that at the end of 1901 there were 246 electrical works in operation, 168 being under municipal control and 78 in private hands. There were also 115 installations being laid down, 84 by local authorities and 31 by companies; whilst public authorities held 147 provisional orders giving them powers to proceed with installations, and companies held 37. During the past three years about 320 provisional orders have been granted, about half of them to local authorities and half to private companies, and of these upwards of three-fourths are for what the author might call small towns, namely, those under 25,000 or 30,000 population.

Seeing then that the prevailing tendency in the smaller towns is to follow the example of the larger boroughs, by adopting electricity for street lighting, the author thought that a paper on the design and arrangement of electric light stations, setting forth the ideas of one who has designed electricity works for the corporation which he represents, and illustrated by drawings of those works, might be of interest to the members of the society and lead to a useful discussion.

It may be mentioned that of the 160 towns in Great Britain that have adopted a refuse destructor, 45 of these installations are combined with electricity works. The author, however, does not intend in this paper to refer in any way to refuse destructor works.

About two years ago the Bridlington Town Council obtained an electric lighting provisional order, giving them power to proceed with an installation. The author was instructed to prepare plans of the works, Mr. F. H. Medhurst, B.Sc., M.I.E.E., of Westminster, being appointed consulting electrical engineer. The plans which illustrate this paper are those prepared by the author. They were unanimously approved by the town council, together with Mr. Medhurst's plans and specifications for the engines, boilers, dynamos, etc. Tenders were invited and sent in, and on May 11 last the tender of Messrs. G. Storr & Son, contractors, of Bridlington, for the buildings was accepted, the amount being 5,238*l*. The total cost of the works is 26,500*l*. The following is a description of the buildings:—

ENGINE HOUSE.

Floor Area.—The floor area of an engine house will depend upon the type of engine or engines to be used. It is a mistake to cramp up an engine house. If more than one engine is required then ample space should be left between each engine for the purpose of overhauling or repairing one or more whilst the others are working. It is unreasonable to suppose that an engineer can thoroughly overhaul an engine if he is so limited for room that he can scarcely turn without being in danger of being caught by the next engine. Several feet space should also be left adjoining each wall of the engine house, to allow of persons passing in and out without disturbing in any way the attendant in looking after the engines.

Future Extensions.—To allow for a possible future extension one end of the engine house should be built in a temporary manner. Wood framing formed of, say, 6-inch by 4-inch and 4-inch by 3-inch quartering, with matchboarding (say, $\frac{7}{8}$-inch or 1-inch) inside, and galvanised iron sheets or rough boarding outside, but preferably the former, makes a good temporary end.

Height.—Plenty of head-room is necessary, so that the overhead crane can run to and fro with perfect freedom. Not only so, but it is often found to be necessary, when extensions are required, to replace the crane which has been in use by a more powerful one, so that ample provision should be made in fixing the height of the engine house for this. It is well to err on the liberal side. The height from floor to rails is usually 18 feet to 24 feet.

In the engine house of the Bridlington Electricity Works the three points already referred to are dealt with as follows: Floor area, 1152 square feet (32 feet wide by 36 feet long). Provision is made for future extensions in the manner already referred to. The height of the engine-house, from floor level to top of girders carrying the overhead crane, is 19 feet. The height to bottom of steel roof truss is 25 feet.

Walls.—The walls should be built in cement mortar (say, 4 to 1), and should be calculated to withstand, not only the strains due to the overhead crane and the thrust of the roof, but also the vibration set up by the engines. In a moderate-sized engine house 18 inches thickness should be sufficient, provided the walls have proper footings on a good foundation of Portland cement concrete, say 2 feet in thickness.

Piers.—Piers should be placed where required to support the girder or arches carrying the overhead traveller. They should stand out from the main wall not less than 9 inches, and should be corbelled out to receive bed-stones for crane (say, 18-inch by 14-inch by 9-inch bed-stones). The piers should be not less than 2 feet 3 inches in width, and should be built in cement mortar 4 to 1. To give them a neat appearance they are sometimes built with bull-nosed corners.

Glazed Bricks.—It is a decided advantage to have the walls of an engine house lined with glazed bricks. They give a light and cleanly appearance, and there is no fear of any brickdust getting into the machinery. At the Bridlington works the author has adopted the following method.

A chocolate-colour glazed dado, 6 feet in height, around all walls, set out as follows:—Chocolate glazed bricks to a height of 5 feet, then a course of white glazed bricks, followed by two courses of chocolate glazed bricks and an ornamental moulded course of the same colour. Above this dado, to a height level with the top of piers (viz. 18 feet from floor level), white glazed bricks, the finishing course being moulded chocolate glazed bricks. Above this the walls are faced with ordinary kiln bricks, rendered over with patent granite plaster ½ inch in thickness, composed of 4 of sand to 1 of plaster; this receives three coats of "Duresco" colour-wash. Bull-nosed glazed bricks are put to all door openings, etc. The author recently had his attention drawn to an engine house where the walls were lined with glazed tiles. An ornamental dado was formed to a height of 5 feet with 6-inch by 6-inch by ½-inch tiles, and above this 6-inch by 3-inch cream-colour tiles.

Where economy is of special consideration, the walls may be built with ordinary kiln bricks and limewashed, but the author thinks it is far better, and in the end more economical, to put in a glazed brick dado say 6 feet in height, or at any rate to form a dado to that height with parian cement, painted and varnished; above this dado the walls could be limewashed.

Overhead Crane.—It does not at all follow that because an overhead crane is used in an electric light station that it is worked by electric power. The reasons being that: (1) It is of comparatively small power; (2) it is seldom used; (3) the time when it is most required is when there is no supply of current, viz. when the machinery is being first erected.

In small power stations, at any rate, it is usually worked by hand from the floor by ropes. Where, however, a 20 or 25-ton crane is put up, it is as well to equip it with electric power.

For a small station, a 10-ton crane should meet all requirements. This should run on flat-bottomed steel rails on girders of rolled steel, say 12 inches by 6 inches, or 14 inches by

6 inches, trussed with wrought-iron tie rods carried through the wall, where a circular iron plate is attached. The girders should be stiffened at ends by gusset pieces. Struts of cast iron are sometimes bolted to underside of girders. The end carriages to be of cast iron, box section, provided with pockets to receive the ends of girders. The crane should of course be fitted with the necessary hoisting gear, also brake, chain, slings, etc., and should be guaranteed to have been well tested at the maker's before being fixed.

Light.—It is very essential where machinery is employed to have as much light as possible. One-seventh of the roof surface may with advantage be skylight, and about one-sixth of the total wall area should be devoted to windows, which should be large, and reach to a height just below the girder carrying the overhead crane. A convenient size for the windows, which should be of cast iron, is 8 feet by 4 feet, with semicircular heads, a portion of the upper part of the window being made to open hopper fashion. The window openings should be formed with bull-nosed glazed bricks, the windows should be glazed with good rolled glass, and the skylight with patent roof glazing such as Heywood's, Helliwell's, Rendle's, or Mellowes' "Eclipse" glazing.

In the Bridlington engine house it will be seen that the light is all obtained from skylights. This is unavoidable, owing to the works abutting upon private property, the owner of which objects to windows overlooking his land.

Ventilation.—Ample ventilation should be provided, and this can easily be obtained from the hopper ventilators in the windows, and the glazed roof ventilators forming part of the skylight; these ventilators should be easily worked by means of some patent roof ventilator openers, such as Leggott's. They may be opened in single bays, or arranged so that two or three bays open at the same time.

Engine Bed.—Engines need a specially good foundation of Portland cement concrete. This of course varies with the type and weight of the engine. The thickness may be from 5 to 20 feet, and the concrete should project in plan from 2 to 5 feet all around the engine base. For an engine of 160 H.P., a depth of concrete of 8 feet is quite sufficient; the concrete should be mixed, say in the proportion of 4 to 1. On the bottom 6-inch layer of concrete, the anchor plates for the holding-down bolts should rest. To allow of a little play, and probable future removal, the bolt is often encased in a wrought-iron tube. When a race for the fly-wheel has to be made, it should be lined with white glazed bricks. The dynamos should also rest on good concrete beds.

Floor.—The floor is sometimes paved with flags, but it is a better arrangement to have it paved with red Staffordshire encaustic tiles laid herring-bone fashion on 6 inches or 9 inches of concrete. The cover plates to the trenches can then be filled in with red tiles to match the floor. The size of the tiles might be 6 inches by 3 inches by ½ inch with 9 inch border. The author has known an engine house to be paved with terrazzo paving on concrete, and this looks very well, but it is somewhat costly. Encaustic tiles on concrete always look very well, and the author knows of an engine house where black and white encaustic tiles were laid, and which look very effective.

Trenches.—An open trench should be left at the back of the switchboard, the latter standing out about 4 feet 6 inches from the wall. The trench leading away from the switchboard should be covered with cast-iron cover plates, filled in with red tiles to match the floor. The trench behind the balancer foundation should be covered with ¾-inch cast-iron chequer plates. The trenches may be formed in 4½-inch brickwork, and the bottom of the trench may consist of 6-inch Portland cement concrete. A convenient size for the trench is 2 feet 6 inches wide by 2 feet deep. If the trench exceeds 2 feet in depth it should be built in 9-inch brickwork. The walls of trenches will be finished with a 6-inch by 4-inch stone coping rebated to receive covers.

Drains or Culverts.—All drains and culverts should be large enough to carry away the waste steam and condenser water. They should be formed of concrete, with manholes here and there for inspection and cleansing purposes.

Roof.—The roof should be supported by light steel roof trusses, placed not more than 8 or 9 feet apart, and resting on stone templates, say 14 inches by 9 inches by 6 inches. The roof should be close-boarded and covered with roofing felt, so as to be thoroughly watertight. Slates are far preferable to tiles. Brackets should be inserted in the walls to carry pipes or stays.

Doors.—There should be a pair of large broad doors, running on rollers, at the temporary end of the engine house, say, 7 feet wide by 8 feet high, and a small door communicating with the accumulator room or outside passage. Although it is very necessary that access from the engine house to the boiler house, and *vice versâ*, should be as direct as possible, still it is preferable that there be no direct communication, as is the case in many generating stations, the reason being that dust is then prevented from getting into the engines from the boiler house, where there is always more or less flying about.

Boiler House.

Situation.—The boiler house should adjoin the engine house, and should have easy access to it.

Floor Area.—The floor area of a boiler house depends entirely on the size, number and type of boilers. The boiler house shown on the Bridlington plans has a floor area of 2111 square feet, is 33 feet 6 inches by 63 feet, and accommodates two Lancashire boilers, each 7 feet 6 inches diameter and 30 feet in length. The boilers should be placed as close together as the arrangement of flues and seatings admits; ample space should, however, be left for the stokers to perform their work with perfect freedom and not be in any way cramped for room.

Floor Level.—This should be several feet below that of the engine house. In the Bridlington design it is shown as 8 feet.

Foundation for Boilers.—A good foundation of concrete, say 5 to 1, is necessary for each boiler. In calculating the weight of the boiler it is necessary to include water and fittings. Concrete 2 feet in thickness should be sufficient.

Future Extension.—As with the engine house so with the boiler house, provision should be made for future extensions. This may be done by building one side of the boiler house in a temporary manner, as shown on the Bridlington plan. Galvanised iron sheeting fastened to tee-iron and angle-iron framing is the method adopted, the roof being supported by 12-inch cast-iron columns 24 feet high, with 15-inch octagonal bases and 18-inch by 7-inch rolled steel joists.

Height.—The height of the boiler house from floor level to under side of roof trusses is 25 feet, and, as the boiler house is sunk 8 feet, 17 feet only, to eaves, is seen in elevation.

Walls.—The walls are 14 inches in thickness, with a number of piers, which are seen in elevation. The walls will be built in cement mortar, 4 to 1, and the portion below ground level, acting as a retaining wall to support earth, will have a vertical damp-proof sheeting of Callendar's bitumen inserted in the centre of the wall to prevent the damp striking through. The best method of dealing with the inside face of the walls in a boiler house is to limewash them, the inside of galvanised iron sheeting on the temporary side being painted a light drab colour.

Light.—There should be a good light in the boiler house, but not so good as in the engine house. A number of large cast-iron windows with semicircular heads placed on the permanent side and end of the engine house, together with about a quarter of the roof covered with patent glazing, will be found to be ample.

Ventilation.—There is more need for thorough ventilation in the boiler house than in the engine house. This can easily be procured by having hopper ventilators to each of the windows, by louvre ventilators in the roof, extending the full length of same and arranged so that they open or shut, and 9-inch by 6-inch terra-cotta wall ventilators placed here and there.

Floor.—It is a good method to pave the floor with flags, either York flags, Victoria patent stone, or some such paving flags, on, say, 6-inch or 9-inch Portland cement concrete. Some boiler houses are paved with blue bricks on concrete. The author certainly thinks paving flags preferable.

Trenches.—All trenches should be covered with wrought-iron chequer plates.

Iron Staircase and Gangway.—Leading from the boiler house to the engine room there should be an iron staircase and gangway formed of chequer plates, supported by light steel joists, carried on cast-iron brackets built into the wall, or cast-iron columns. The handrails should be formed of wrought-iron tubing.

Roof.—The roof should be supported by steel roof trusses placed 8 or 9 feet apart. The roof should be close-boarded and covered with felt and slates, as in the engine house, the underside of the boarding being painted some light colour.

Drainage.—The drainage for the scum and blow-off cocks, water-gauge cocks, etc., may be carried into a sump, which should be built in 14-inch brickwork in cement, backed up by 9 inches of puddled clay, and cemented inside, with 12 inches of concrete to form floor and foundation to sump. The sump should be covered in with rolled steel joists and concrete, and provided with a manhole cover, step irons, etc., for inspection purposes, and an overflow, and should be properly ventilated. For the purpose of emptying the sump an ejector may have to be employed.

Coal-bunker.—The coal-bunker should be of a fair size, and placed as near to the furnaces as possible; it should also have easy access. It is an advantage to give it a sloping floor. The size of the one illustrated is 23 feet by 8 feet 6 inches; it is 6 feet in height, is covered in with 8 inch by 6 inch steel joists and concrete, and has three manhole openings.

Inclined Footway.—An inclined footway running parallel with the temporary side should lead to the boiler house; this should be about 6 feet in width, and have a gradient of not more than 1 in 6. It may be paved with blue Staffordshire bricks, 9 inches by 4½ inches by 3 inches, chequered on face, and laid flat on 6 inches of Portland cement concrete, and grouted in with cement, or it may be formed of stone setts on concrete, and would of course drain on to a gully placed at the bottom of the incline. Such a footway would be found to be most useful for the purpose of wheeling ashes out. The footway is enclosed by a 3-foot 6-inch close boarded fence. Sometimes, instead of an inclined footway, an inclined hoist is used for the purpose of removing the ashes.

Doors.—The entrance to the boiler house at the bottom of the inclined footway should be by means of folding doors, say 6 feet width of doorway by 7 feet 6 inches in height. A small door should lead from the gangway indirectly to the engine house, and it will be seen from the plan that there is a large doorway (12 feet by 5 feet 6 inches) placed near the heater; this is arranged as a means of access to the heater. The heater is built up in sections, which are readily removable for cleaning purposes. The doorway is arranged so that these may be removed outside the building for cleaning, and to facilitate this a joist is shown. On the lower flange of this joist run a set of chain blocks, and the joist is well stayed at its outer ends and well supported at the centre by being bolted to a cross girder built into the wall.

Flues.—The flues should be lined with 9 inches of firebrick set in fireclay; radiated bricks only should be used, and they should be well wetted before use. There should be 2 inches of space between the firebrick lining and the ordinary bricks. Dampers should be provided for regulating the draught.

Accumulator Room.

Floor Area.—On no account should the floor area be cramped; it is far better to err on the other side, by making this room too large rather than too small. It should be of such a size that in the event of the works being enlarged, there will be no need to enlarge the accumulator room. At Bridlington, the area of the accumulator room is 726 square feet (22 feet by 33 feet). This room accommodates a battery of 236 cells. Water supply is laid on and a sink is provided.

Light.—Although there is no necessity to make this room as light as the engine house, it is, however, very essential that it should be fairly light. The author remembers once going into an accumulator room that was almost dark. The windows should be large and well proportioned, and the top of same extend almost to the ceiling line.

Fire Prevention.—It is very necessary in designing an electric light station that every material of a flammable nature be omitted as far as practicable.

Flooring.—At Bridlington the floor is paved, as in the engine house, with red Staffordshire tiles on 6 inches of Portland cement concrete. The floor above the accumulator room might have been carried by means of rolled steel joists and concrete, but the author has adopted a somewhat different method, viz. Stuart's elliptical arched "granolithic" fireproof flooring, carried on four 14-inch by 6-inch rolled steel joists, supported by brick piers and iron columns, as shown on the plan. This presents a good appearance from the underside, and makes an admirable fireproof floor; and is, in the author's opinion, not only a lighter, but also a stronger floor, and certainly more proof against fire than the ordinary method of rolled steel joists and concrete.

Height.—The height of the accumulator room will be proportioned to its size, and should not be less than 13 or 14 feet.

Walls.—There is no need for glazed bricks in this room, but the walls may be built with good kiln bricks, and colour-washed (some light colour) with say three coats of "Duresco" colour-wash; they are often only limewashed.

Ventilation.—Ventilation should be chiefly effected by means of hopper ventilators in the windows, but it is also advisable to have one or two terra-cotta air bricks, say 9 inches by 6 inches, in the walls. Ventilating fans are sometimes employed very effectively to ventilate this room.

Store Room.—It is very necessary that ample storage accommodation should be provided, and the author thinks it is preferable to have two store-rooms, a large one, and a smaller one, the former to contain heavy goods, and the latter, oil, waste and lighter goods.

Meter Room.—No works are complete without a room set apart for the purpose of storing meters.

Staircase.—The staircase should be constructed of fire-proof material; the author has specified 13-inch nosed treads, and 7-inch risers formed of granolithic material, and backed up with brickwork.

Workshop.—A portion of the works should be set apart as a workshop, and should be sufficiently large to contain lathes, drilling and milling machines, fitters' bench, forge, etc. It should also be provided with cupboards and lockers. A convenient size for this workshop would be about 25 feet by 14 feet. Plenty of light should be provided, and folding doors, say 6 feet 6 inches width of doorway by 7 feet 6 inches height, should be allowed for. Ventilation can be obtained from windows with hopper ventilators, and air bricks. It is advisable to have the workshop as near to the large store-room as possible. Of course where the works are very small, and no repairs of any size are intended to be undertaken by the staff, there is no need for a workshop.

Lavatory Accommodation.—Ample lavatory accommodation should be provided. A w.c. and lavatory should be placed for the use of the engineer as near to his office as possible. A urinal, one or two w.c.'s (according to the size of the works), and lavatory basins should be provided for the use of the men. On some works a bath is also provided. Sometimes the men's lavatory and w.c.'s are placed in the main building, and sometimes they are put in a small outbuilding as shown on the plan.

Engineer's Office.—The engineer should have a private office, which is usually placed on the first floor. It should be provided with a fireplace, and have plenty of light, and should be fitted up with rolled desk, drawing table, cupboard and other suitable fittings. It is a good arrangement to have the flooring of wood blocks on concrete, say, $1\frac{1}{4}$-inch pitch pine blocks laid herring-bone fashion. In larger works a drawing office and clerks' room is also provided, but in smaller works these are not needed.

Men's Room.—In some stations a mess-room for the men is added, and this is a great acquisition. This room should be not less than, say, 20 feet by 10 feet, and should be provided with a fire-place and plenty of light and ventilation. Where a refuse destructor and electric light works are combined such a room is almost a necessity.

Water-Storage Tank.—Where a water-storage tank is required it should be formed of square cast-iron plates planed to template, and strongly stiffened with brackets, and flanged. The tank should be well stayed with wrought-iron tie-rods, and made perfectly watertight. If the tank is a very large one the floor and lower side plates may, for economy's sake, be of thicker plates than the middle and upper plates. For example, assuming the tank to be 50 feet by 20 feet by 12 feet, and the plates 4 feet square, the floor and lower side plates might be $1\frac{1}{8}$ inch thick, the second row of side plates 1 inch thick, the third row $\frac{3}{4}$ inch thick. The tank may be covered in by plates $\frac{5}{8}$ inch thick, resting on joists and angle irons. The tank may be supported in many ways: either by a brick tower, brick piers, or by a wrought-iron trestle, or by iron columns well braced together. To record the amount of water in the tank a water-level recorder should be fixed in it, and an automatic indicator placed in the electric light station. The tank should be well painted with oxide of iron paint, inside and out.

CHIMNEY SHAFT.

Constructional Importance.—Perhaps no constructive detail is so important as the chimney shaft. If the works are only of a temporary nature the shaft is sometimes built of iron plates, say ¼ inch in thickness, riveted together with ⅝-inch rivets and lined with firebrick, but where the buildings are intended to be permanent a brick shaft should be erected. This may take the form of a square, octagon, or round shaft.

Wind Pressure.—A circular or octagonal shaft is preferable to a square one, as offering less resistance to the wind. Rankine gives the greatest wind pressure that has ever been observed in this country as 55 lb. per square foot, but it is necessary to allow for a higher wind-pressure than that, say 65 lb. per square foot. Molesworth gives the relative wind-pressure on a square, octagon, and round shaft as follows: square 1, octagon ·65, round ·5.

Width of Shaft at Base.—The external diameter of a chimney shaft at its base if square should be one-tenth of its height, if octagon one-eleventh, and if circular one-twelfth of its height. The diameters of circular shafts over 300 feet high are sometimes made as small as one-fourteenth of the height.

Natural Foundation.—Nothing is so important in erecting a shaft as a good foundation. The width and depth of the concrete foundation will vary according to the nature of the subsoil. Rankine says that the safe load per square foot on natural compact earth should not exceed 1·0 to 1·5 tons. Prof. Adams says it may equal 2 tons, whereas Trautwine says that 2 or 3 tons per square foot are safe. If we take 1·5 tons per square foot the author thinks it will be quite safe. If the concrete foundation rests on clay the safe load per square foot will vary from 1·0 to 2·5 tons, according to the nature of the clay. A chimney at Newcastle, resting on a compact clay foundation, has a distributed load per square foot of 1·5 tons. The Cleveland viaduct, resting on blue clay, has a distributed load per square foot of from 1·0 to 1·7 tons. The distributed weight on the clay foundation of the chimney shaft of the Southend electricity works is 1·33 tons per square foot.

Concrete Foundation.—The foundation should be of Portland cement concrete, say 5 or 6 to 1, and will vary in thickness from 6 to 14 feet. Given a clay foundation, a chimney 150 feet high may stand on a good bed of concrete 20 or 22 feet square by 7 or 8 feet thick. The concrete should be well rammed in in layers not exceeding 6 inches in thickness; on no account should the concrete be thrown into the excavation, but it should be lowered and spread, and after the whole of the concrete has been put in it should remain at least three weeks before any brickwork is placed upon it, in order that it may have thoroughly consolidated and that any settlement may have taken place. Where the natural foundation is somewhat treacherous, owing perhaps to the locality being undermined with coal or other mines, it is a good plan to insert in the bottom of the concrete rolled steel joists, with cross joists bolted to them forming a raft or platform. In one instance which has recently come under the notice of the author, 54 girders were used to form this platform, 36 feet × 6 inches × 5 inches, inserted in a concrete bed 36 feet × 36 feet × 6 feet deep. The safe load per square foot on cement concrete may be as much as 4 tons.

Footings.—Upon the concrete foundation brick footings, set in cement mortar, should be placed. The footings should extend on either side of the wall the width of the wall at base.

Thickness of Brickwork.—The thickness of the brickwork of the shaft is calculated as follows: first 25 feet from top 9 inches thick, unless the shaft is more than 5 feet internal diameter at top, as at Bridlington, where it should be 14 inches thick for the first 25 feet, with 4½ inches set off every 25 feet, thus making the brickwork of a shaft of 150 feet height nearly 3 feet thick at its base. The shaft should have a batter of 2½ inches in every 10 feet of height.

Bond.—The shaft should be built in the following bond: 1 course of headers to 3 or 4 courses of stretchers.

Mortar.—Chimneys should be built in lime mortar, and not in cement, for two reasons: (1) cement is too rigid, and does not give the chimney sufficient play in a strong gale of wind; (2) it does not stand the heat so well as lime mortar. The author thinks, however, that there should be a little cement in the mortar, and for the Bridlington shaft he has specified the mortar to be composed of 4 parts of best grey lime to 8 parts sand (mixed in the proportion of 2 of land sand to 1 of sea sand), to 1 part of Portland cement. Of course the resistance to crushing is somewhat reduced by using lime mortar instead of cement. Revington gives the working stresses of brickwork in mortar as, compression, 0·5 cwt. per square inch; adhesion, 0·06 cwt. per square inch: in cement, compression, 0·8 cwt. per square inch; adhesion, 0·1 cwt. per square inch; but this reduction of 35 per cent. in the compressive strength and 40 per cent. in the adhesive strength is not considered.

The brickwork should proceed slowly; say, not more than 3 or 4 feet per day, so that the mortar may thoroughly set before the weight comes upon it, and the joints should not exceed ¼ inch in thickness and be pointed with a neat flat joint. Every other course of brickwork should be grouted in. Chimneys are usually built from the inside, internal scaffolding being used. Where the shaft is in a prominent position scaffolding on the outside is sometimes erected to a height of, say, 30 feet, for pointing purposes.

Density of Bricks.—The safe load per square foot on brickwork in mortar may be 4 tons (stock bricks in grey lime mortar), or 5 tons in lias mortar. Very often in chimney shafts this is exceeded. For example, the Merchants' shot-tower at Baltimore, U.S.A., is 246 feet high, and its base sustains 6½ tons per square foot. The St. Rollox brick chimney, at Glasgow, is 468 feet high, and bears 9 tons per square foot. Rankine says, that in a high gale of wind its leeward side may have to bear 15 tons per square foot. He considers, however, that 7 tons per square foot ($\frac{1}{10}$ ultimate) on good strong bricks should be the utmost limit.

It is very necessary that all bricks should be of the same density, so that the weight is uniformly distributed. The principle sometimes adopted of facing the shaft with bricks altogether superior to those used for backing is a mistake. The bricks should all come from the same kilns, and if the face-bricks are to be superior to the others, they must only be superior in the sense that they are picked out as being more true in shape, or more uniform in colour, and not that their density is superior to the others. Specially made angle-bricks should be used for all angles in octagonal or hexagonal shafts. Shafts are usually built with square pedestal bases, with moulded plinth and sunk panels. Ornamental bands of brickwork should be formed in, say, six courses of blue Staffordshire bricks, or some bricks that are, if anything, of superior density to the bricks of which the shaft is built; on no account should a brick of less density be used.

Caps.—The caps are made of iron, terra-cotta, or stone, and should not project more than the thickness of the brickwork. The design adopted by the author at Bridlington shows an ornamental coping built of brick and stone; the stones are bonded together, set in cement 1 to 1, and well secured with gun-metal cramps run in with lead. The cramps usually employed for this work are of iron, but gun-metal or copper is far preferable. The depth of the stone coping is 3 feet 6 inches, and a cast-iron cap, built in sections, with a flange projecting downwards encircling the stonework to a depth of 18 inches, is fixed on top, and is well bolted together and securely fastened to the stone. Sometimes, in circular shafts with stone caps, gun-metal rings are inserted instead of cramps for holding together the stonework, and are far preferable.

Ornamental Stonework.—The pedestal base is usually surmounted with a fairly heavy stone cornice, the quoin stones of which should go right through the wall, and near to the top of the shaft an ornamental stone string-course is usually inserted; these should be built in cement. In the Bridlington design the former is 2 feet in depth and projects 2 feet; and the latter is 2 feet 6 inches in depth and projects 1 foot. All the stonework is of the best Yorkshire stone, and is carried well into the brickwork.

Firebrick Lining.—For ordinary heats the firebrick lining may be carried up to, say, 30 feet, but if the heat is considerable, it should be double this; and where the fumes from a refuse destructor are likely to pass through the shaft, the firebrick lining should be carried up, say, two-thirds of the height of the shaft. Some engineers prefer it to be carried right to the top. It will be noticed on the Bridlington design that the firebrick lining is carried up 110 feet; this is on account of the probability of a flue from a refuse destructor being connected with it at a later date. The thickness of the firebrick lining up to a height of 60 feet is 9 inches, and beyond this 4½ inches. The firebrick lining is tied into the main brickwork by means of firebrick bonders. A space of two inches is left between the lining and the main wall, and a sailing course covers this space to prevent soot, etc. from getting down behind. The best Stourbridge firebricks only are used, and are set in pure fireclay cement. Of course, in calculating the thickness of the brickwork, the firebrick lining is not included.

Arched Openings.—An additional arched opening is formed in the base of the shaft for the connection of a flue from the refuse destructor at some future time. This opening is built up with 18-inch brickwork, consisting externally of 9-inch common bricks, and internally of 9-inch firebrick.

Step Irons.—Step irons are fixed to a height level with the top of the firebrick lining.

Lightning Conductor.—The best form of lightning conductor is undoubtedly a solid copper tape. The usual sizes are ¾ inch, 1 inch, and 1½ inch wide by ⅛ inch thick. The conductor should not be carried around projections, but through them, whenever possible, to avoid unnecessary deviation from a direct course to earth. It should have at the top four or five terminals of stout steel, thickly copper-plated, the lower ends of the conductor being attached to earth-plates buried in the ground. The tape should have as few joints as possible, but where it has to be joined the union should be effected by means of copper rivets. The connection of the spear to the conductor may be made by means of a stout screwed coupling. The holdfasts should be of copper or gun-metal, and it is far preferable in constructing a chimney to build into the brickwork specially made fixings as the chimney proceeds. The size of the copper earth-plate is governed by the nature of the earth: 6 square feet area by $\frac{1}{8}$ inch thickness is very common. The lower part of the conductor is riveted to the earth-plate with copper rivets. The copper tape should be not less than 90 per cent. conductivity. A properly constructed lightning conductor is calculated to protect a space equal to a cone whose sides and base form an equilateral triangle.

Inside Diameter of Flue.—The inside diameter or area of a flue and height of shaft depend on the volume of air required for the combustion of the fuel, the temperature of the escaping gases, and the resistance caused by friction; but as some of these particulars cannot be ascertained beforehand, it is necessary to adopt an empirical formula. The following has been found to answer very well in practice:—

Let A = area of chimney at top in square feet.
H = height of chimney above fire-bars in feet.
F = consumption of fuel in lbs. per hour.
C = ·1 for coal.
C = ·09 for coke.
C = ·06 for wood.

Where fuel consumed is under 500 lb. per hour, $H = \frac{F}{20} + 65$.

„ „ above „ „ $H = \frac{F}{50} + 100$.

The height of a shaft above ground is determined chiefly by the necessity to produce a draught. The following has been found in practice to meet most requirements:—

Consumption of coal per hour.	Height of Shaft.
100 lb. and under	60 feet
500 „ „	100 „
1000 „ „	120 „
2000 „ „	140 „
3000 „ „	160 „
4000 „ „	180 „
5000 lb. and upwards	200 „

It will be noticed that in the design of the Bridlington Electric Light Station the shaft is much larger than is necessary for present requirements. The reason for this is to allow for a flue from a refuse destructor being connected, also to allow for extension of the works, and for the possibility of power being added to the works for electric tramway purposes.

DISCUSSION.

The PRESIDENT said that he had much pleasure in moving a hearty vote of thanks to Mr. Matthews for the interesting paper which he had read to the Society.

The vote was carried by acclamation.

Mr. EDWARD WILLIS said that the paper had been a very interesting one. There were, however, a few points upon which he ventured to differ from the author, having had recent experience in some important stations, but as the paper was full of detail he would deal with them seriatim.

The author dealt with future extensions, and the plan which he recommended was a very good one, but there was one which was even better for large stations where extensions were frequent, and which had been adopted by the Metropolitan Electric Supply Corporation. That was to arrange a corrugated iron end in the engine-house and the boiler-house, supported by steel-braced framework, on wheels. By means of short rails, the whole of the temporary framework could be moved forward every time another 5000 H.P. engine or further boilers were required.

With regard to glazed bricks, he had had a very unpleasant experience. In the Willesden works, glazed white bricks were used throughout, with a green dado, in the engine-house, and salt glazed dado in the boiler-house; but, unfortunately, the contractor for the travelling crane had to drill the supporting girders for its erection after the brickwork was finished, and during that work oil was allowed to drop behind the glazed bricks, which spoilt their colour and rendered their appearance very objectionable. It was too large a matter to cut out the stained portions and replace them.

Under the heading of "Light" Mr. Matthews mentioned that one-seventh of the roof surface was skylight. His (Mr. Willis's) experience was that one-half might with benefit be substituted for one-seventh, although he had seen the whole surface glazed and then the light had not been excessive. One-half was allowed in the Willesden District Council generating station, and it was not found too much considering that the upper surface was liable to become darkened by deposits of soot. In that case they were unable to obtain light in the side walls, either in the boiler-house or in the engine-house.

A very important matter in connection with the roof of the engine-house was the condensation of moisture upon the underside of the glazing, and the dripping of the water upon the dynamos; and provision should be made to remove every drop of condensation water.

Mr. Matthews stated that the mains should be covered with cast-iron cover-plates or rolled chequer plates. He differed from him on that point. It was objectionable to be continually cutting plates as the number of mains increased. He had found by experience that teak or oak covers were preferable, except in the boiler-house or directly adjoining the engine.

As to the drains, he thought that it was preferable to form them of cast iron or stoneware, rather than of concrete, because there was a tendency for the water and oil to soak into the concrete bed, which was most undesirable.

With regard to roofs, Mr. Matthews said that slates were far preferable to tiles. He (Mr. Willis) had used both, and he admitted one was a great deal more economical than the other, but not necessarily better; in fact, tiles were decidedly more fireproof than slates.

The author had given the height of the doors of the engine-house as 8 feet. That might be sufficient in a small station, but he (Mr. Willis) would strongly urge that the height of all main doors in electricity generating stations be made more than that. It was very difficult to get the preliminary plant in on a trolley with a doorway of only 8 feet high.

In theory he agreed with Mr. Matthews as to there not being a direct communication between the engine-house and the boiler-house, but in practice he did not agree with him, for there were exceptional times when immediate access to the boiler-house was required. A door should be provided for emergencies, but it could be kept closed, and should bear a notice that it was only to be used on emergencies.

He could not see any reason for making the level of the boiler-house several feet below that of the engine-house. He agreed that Mr. Matthew's design was admirable, but he did not think that the difference of level would be applicable in all cases.

As to movable ventilators, he knew in practice that these were constantly kept open, and often refused to act if attempted to be shut; he therefore suggested for a boiler-house plain open louvres, which would answer equally well and be cheaper.

On the subject of the flues, he did not agree with the author as to the absolute necessity of an air-space, but that subject was rather a vexed one.

He also differed from the author with regard to a workshop being unnecessary in a small station. There were always repairs which must be undertaken by the staff, and a workshop was necessary for their execution.

He was afraid that he must absolutely differ from Mr. Matthews as to the provision for the wind-pressure on the chimney shaft. He (Mr. Willis) agreed with Rankine that it was sufficient to provide for a maximum resistance of 55 lb. to the square foot. He thought that figures went to prove that no greater wind-pressure had been registered than 44 lb. per square foot when taken over a large area; and he knew of one shaft 140 feet in height which had withstood all gales within the last twenty years, but which would have fallen had the pressure exceeded 50 lb. per square foot.

He was sorry to say that he differed from Mr. Matthews with regard to the formation of the concrete bed. He thought that it would be much more beneficial to deliver the concrete in large masses from a height of about 10 to 15 feet, provided there was efficient supervision to see that the material was properly prepared and worked into a uniform mass *in situ.*

As to the thickness of the brickwork in the chimney shaft he agreed with the author, but he thought the Metropolitan Building Act required a greater thickness than that shown on the drawings.

The step-irons were shown to be bonded through the fire-brick into the common brickwork. That seemed to him (Mr. Willis) wrong both in theory and practice, owing to the different ratios of expansion and the shrinkage that would occur in the fire-clay of the fire-brick work. He had had several conversations with experts as to the use of step-irons, and he did not think that they would be used after the fire had been in for more than a year. The gases in the flue would be sure to corrode the iron in a short time, and a steeple-jack preferred to ladder the outside and drop down inside by rope from the top rather than trust to the step-irons.

As to the lightning conductor, he agreed that the tape was the best, but thought solid copper rods at the top, with platinum points, were preferable; and it was important that electrical connection of corona and iron cup should be perfect.

Mr. H. G. Humby (Consulting Engineer to the Natal Government) said that the paper was full of information to engineers abroad like himself. Such persons were always looking out for information from English engineers. He was now engaged on an electric light and power station works in South Africa, and had he had the present paper before him at an earlier date he should have been very glad to adopt many of the suggestions which it contained.

As to the area of glazing in a roof, he took it that that depended very much on the climate. For instance, in a dull climate like England it might be a very good thing to glaze half the area of the roof. But the same proportion of glazing would be quite out of place in India or South Africa. The glare would be too great and the heat would be unbearable. In South Africa they had to aim at reducing the glazed area as much as possible. That was particularly the case with regard to railway stations.

Mr. Willis had made some remarks in opposition to what the author had said, with regard to depositing concrete in large masses, but he (the speaker) could not agree with the criticism. He preferred having the concrete deposited *in situ*, and having it rammed in or trampled in. That gave a better result than throwing, especially when they had to depend on broken stone. If the stone and mixture was thrown from a height of 6 or 7 feet, the mortar would go into one layer and the stone in another.

Mr. Brierley D. Healey said that the author had spoken of 4½-inch walls. He (Mr. Healey) thought that he would have some trouble with 4½-inch walls. He had tried light work, but he had never found that thickness sufficient.

With regard to what the author called the sump, he preferred what he might call a receiver made of iron or steel plates, sufficiently strong to withstand 20 lb. to the inch. Of course it was a regulation in many towns not to empty such receivers into the sewers until the contents were nearly cold. It was usual to take the sludge out periodically, and, when dry, to weigh it, so that they might know what they were doing. By such weighing and drying of the sludge they would find out how they were working.

As to the chimney shafts, if two intake flues were put at different levels there would never be the same draught in the upper one as in the lower one, taking the area foot by foot into account. He had had to deal with that trouble, and in the case of a destructor chimney he had had to put deflectors to direct the gases which came up, so that each intake had an equal chance of the aspiratory action of the chimney.

As regarded the lining of chimneys, it would be found that there would be nothing but trouble if the inner lining was tied to the main wall. It was of the greatest importance as regarded settlement, and also as regarded vibration of the chimney due to windage, to have the inner lining independent of the outer shell, and with a space varying from 2 inches to 9 inches according to the height of the chimney. He might mention a chimney 300 feet in height which had a lining 9 inches clear of the outer wall. It had been found in a gale of wind that the main wall rocked about 3 inches. A chimney which he built in 1863 was about 308 feet high and had a 15-feet flue. It had no inner lining and no cavity, but he would not now build without a cavity and separate lining. The temperature of the flues frequently rose to 1200° or 1500° F. He mentioned that to show that there was no necessity to make 9-inch fire linings in flues, and that 4½ inches was quite sufficient. In the case of a steel furnace, for instance, with a temperature of 3000° inside and the inside perfectly white, it was possible to put the hand outside at 18 inches from the interior face.

The position of a boiler was quite a matter of convenience. In an electricity works there were reasons why the boiler should be set down in the ground, for sometimes the engineer in charge, in an emergency, wished to get at the valves on the top, and if the boiler was above ground he would have to use a ladder. He thought that the balance of convenience was on the side of having the boiler below the level of the engine-house.

For facing the walls he preferred glazed bricks, but care must be taken to prevent oil from running into the bricks.

It was quite right to have a travelling crane, and for most small works, whether electric or otherwise, it was the best thing to have the crane hand-driven.

As to the drains in the concrete, there was no doubt that they should be either glazed pipes or iron pipes. If the drains were formed of concrete, there would be no end of trouble. Pieces of waste would adhere to the sides and in time the drains would be choked, no matter what the size was.

Mr. R. STEPHEN AYLING said that, perhaps, there were reasons at Bridlington why the boiler-house should be lower than the engine-house, but at most stations both were on a level, and he saw no reason why they should not be.

With regard to the lining of 9-inch brickwork set in fire-clay in the chimney, there was evidently a difference of opinion as to whether the firebrick should be bonded or that there should be a space between it and the ordinary brickwork. His own opinion was that a space between, and the firebrick not bonded, was the best arrangement.

He thought that an electrically-driven fan was the best means of ventilation, at any rate for the engine-house, as it obviated the difficulty of water dripping upon the dynamo, which was of course a very serious thing.

He agreed with the objection to throwing the concrete from a height. When concrete with large stones was thrown in from a height, the practical result was that the stones and the cement or lime settled in distinct layers.

He had frequently seen cases of glazed bricks being stained with oil. A marble floor, which had been recently laid in the engine-room of a station in a London suburb with white and black marble, was seriously deteriorated by oil which had fallen upon it.

He should like to know the result of putting cement with lime mortar in the building of the chimney shaft, as recommended by the author of the paper. The practice was quite new to him.

Mr. E. G. BEAUMONT said that the points upon which different opinions were expressed by engineers were sometimes, as matters of mere opinion, of very little consequence. As to the question of whether the boiler-room should be below the engine-room or on the same level, he should say that in the works that he had seen there were about as many instances one way as there were the other. The chief point was to secure easy access to the boiler top. He should think that it would be probably cheaper to arrange both rooms on the same level, and to have the roofs the same height.

It was usual to have more cubic capacity in the boiler-room, but it was a question as to whether that was really necessary. Good ventilators should reduce the temperature in the boiler-room to that of the engine-room; and the boilers being generally well lagged, and the greater part of their surface protected in brickwork, an inconveniently high temperature might be avoided.

The dripping of water from the roof was a thing which every central station engineer experienced, but he (the speaker) did not understand how it could be prevented. Ventilation by fans was no doubt the best remedy, but it was expensive. Probably the cheapest plan was to provide good covers for the machinery, or at all events for the electrical machinery.

He agreed with the opinion that hand-worked cranes were more suitable than electric, because generally when the cranes were wanted the works were shut down and electrical power was not to be obtained.

Mr. MAURICE WILSON expressed his thanks to the author for his interesting paper, which seemed to be a mine of information, but he thought that it would be more interesting and useful if it gave some details as to the size of the engines and the population that the works were intended to serve.

When he read the paper he was much struck with the constant allusion to glazed bricks and tiles. It was many years since he had to do with an electrical station, but, if he remembered rightly, such things as glazed bricks were not thought of at that time.

He was surprised that the author thought that paving stones were better than bricks for a boiler-house. He should have thought the contrary.

The author had said that the storage water tank ought to be square and made of cast-iron plates. But he should have thought that a wrought-iron or steel tank would be preferable. There was a very fine specimen of a cast-iron tank at the Crystal Palace, and some years ago one of the plates blew out and thousands of gallons of water were precipitated. The falling water dug a hole fifteen feet deep in the ground, killed a man and washed a garden away. The tank was made of huge cast-iron plates, supported by tie-rods going across from one side to the other.

Mr. PERRY F. NURSEY said that he should like to point out to Mr. Wilson that in the case of a very large tank there must be tie-rods, whether the tank was of cast or wrought iron. He thought that, for a tank of the size mentioned by Mr. Wilson, cast iron of proper section, properly designed and properly tied, would be better than wrought iron or steel. At any rate, he should not hesitate to employ cast iron unless there were any prohibitive collateral conditions.

The President said that he felt that the Society owed Mr. Matthews a very great debt for having dealt so much in detail with the various parts of the building which he had described. The paper would be of great use, and especially to the younger members.

He was glad that Mr. Matthews laid stress on the importance of providing plenty of space and plenty of height in the engine-rooms and boiler-rooms. It was scarcely possible to be too careful in making provision for the purpose of ensuring that the atmosphere and the surroundings in those rooms should be healthy and comfortable, for the work of the men was of a very trying character; they worked long shifts and had very onerous duties to perform. It was only fair that men who had to work under great strain should have convenient and comfortable surroundings to work in. The proper designing of an electric station would contribute to the efficiency of the work performed.

He thought that Mr. Matthews was quite right in suggesting that the piers should have rounded corners. Sharp corners were liable to chipping, which was a great disfigurement.

He did not think that it was a good practice to have plastered walls, however they were treated, whether by paint or duresco. The use of plaster in such a case was not economically sound. The first cost of plaster was cheap, but the cost of upkeep and renewal was in the end more than glazed bricks would cost in the beginning. On no account should a dado be made of plaster, for it was exposed to much greater knocking and wear than the upper portion of the wall.

It was, he believed, very desirable that in the glazing of the skylights in an engine-house, armoured plate glass should be used. Wire was inserted in the glass, and if the glass got broken the pieces were retained by the wire, so that they could not fall down upon persons beneath. The material was made by a firm at St. Helen's. Glass of that kind could very well beused in a building in which a great part of the roof consisted of skylights.

For the paving of an engine-house, the best material was, he thought, wooden blocks. The men had to be on their feet for a great number of hours, and flags, asphalte, or concrete paving, or even tiles, was very tiring. Moreover, concrete flooring should be avoided, because the constant traffic over the floor wore that material away; the atmosphere was thereby rendered dusty, the dust got into the bearings of the machinery, and consequently a very great amount of time was taken up in keeping the various parts of the machinery clean.

He agreed with Mr. Wilson that a cast-iron storage tank was hardly present-day practice. He thought that wrought iron or steel would certainly be better.

The bonding of the firebrick lining into the outer shell of the chimney was, in his opinion, a mistake. He thought that it would be far better to have the firebrick lining free.

He was glad that the paper had called forth a very interesting and profitable discussion. The value of a paper dealing with different points in detail was that it brought out the experience of different persons with regard to the points which it mentioned. The discussion which had taken place must be gratifying to the author. Personally, he felt very much indebted to Mr. Matthews for his excellent paper.

Mr. MATTHEWS, in replying upon the discussion, said he had been much gratified at the criticisms which he had heard. He, however, hardly agreed with Mr. Ellis in thinking that a moving framework would be preferable to the fixed temporary ends in works of the size and description of those dealt with in the paper. The station had been designed for a town with a resident population of 14,000 or 15,000, and probably extensions would not be required at shorter intervals than five or six years.

He was much obliged to Mr. Willis for the information that glazed bricks were liable to discoloration with oil, and when the works under notice were carried out he should provide against that disadvantage. He agreed with Mr. Willis in the opinion that if they did away with the light from the side walls, skylights occupying only one-seventh of the area of the roof would not be sufficient. He did not think that he should go to the extent of one-half, but he should probably extend the skylights in that case to one-third or one-fourth of the roof area.

He saw the necessity of being careful with regard to water dripping from the roof of the engine-house on the dynamos in wet weather, and he was glad that that matter had been brought out in the discussion.

As to the drain he quite agreed that cast iron or sanitary pipes would be as useful as concrete, but he would not say that it would be more suitable.

As to 8 feet not being a sufficient height for the door of the engine-house, Mr. Willis must remember that the engine-house only had to accommodate two small engines, and would not be required for machinery such as occupied the works which Mr. Willis had referred to, which had cost 50,000*l*. He thought that 8 feet was sufficiently high for the door.

Mr. Willis had recommended that there should be an emergency door giving direct communication between the engine-house and the boiler-house, and that it should be kept locked at ordinary times. He did not agree with Mr. Willis's view. The door which he had advocated would be of very little additional utility on emergency, and the chances were that it would be often left unlocked when it was not required for use.

With regard to the level of the boiler-house, what he intended to convey was that in electricity works the floor of the boiler-house was generally several feet lower than that of the engine-house. In nine cases out of ten of those that he had seen that was the case. No fixed rule could, however, be made with respect to that, as sometimes it was an advantage to have both floors on the same level.

As to ventilation, there ought, in the boiler-house, to be louvre ventilators made to open and shut. He must enforce that point. Sanitation was a matter of very great importance. If the workmen kept those ventilators closed, or kept them open at wrong times, that would not be the fault of the architect who designed the building.

As to the space in the flues between the firebricks and the common bricks, Mr. Willis thought that there was a great difference of opinion upon that point, because sometimes he had found space left and sometimes not. The general rule in electricity works was to leave a space.

He did not agree with Mr. Willis in the opinion that there should be a workshop at every station. If any repairs were required at a small place like Bridlington they would be sent away to Leeds or Bradford or Hull, and not executed on the spot.

As to the wind-pressure, he certainly thought that 65 lb. to the foot was none too much to allow. Rankine said 55 lb. wind-pressure had occurred in this country, and if that was so they ought to allow 65 lb. in order to be on the safe side. There was no comparison between the wind-pressure on the Forth Bridge and the wind-pressure on a chimney-shaft.

He must adhere to what he had said about the concrete being put in in layers. He found, in carrying out works at Bridlington, that the contractor would shoot the concrete into the trenches if the engineer's back was turned for five minutes; and he had found the cement lying in one direction and the ballast in another direction. It was necessary to insist on the concrete being lowered into the trench, and then spread and rammed in.

He noted Mr. Humby's remark that the area of light required in South Africa would not be so large as was required in this country.

He hardly agreed with Mr. Healey that the 4½-inch walls to the trenches would be insufficient, and he thought that that thickness was quite enough for walls only 2 feet high. Mr. Healey's idea as to the blow off going into a receiver and then passing into the sump was a capital one.

A remark was made by Mr. Healey as to the effect of flues coming in at different levels. These flues which he (Mr. Matthews) had designed came in at the same level. There were many points in favour of the firebrick lining being bonded into the main wall, and many against it; but he certainly thought that there should be some bonders, if only a few, in order to make things secure. Mr. Healey had remarked that a chimney of 300 feet should have a space of 9 inches left between the firebrick lining and the main wall of the shaft. He should like to point out that the chimney at Bridlington was only 150 feet in height, and he thought that for that height 2 inches of space was quite sufficient.

Mr. Ayling had suggested an electrical fan for the ventilation of the engine-house as preferable to roof ventilators. But he (Mr. Matthews) did not think that that was preferable in small works. He could not tell Mr. Ayling what the effect of putting a little cement into lime mortar would be, for the place had not yet been built.

A question had been asked by Mr. Maurice Wilson as to the size of the town for which the works were designed, and why no particulars had been given respecting the machinery. In reply he would draw Mr. Wilson's attention to the title of the paper, which was, 'Electric Light Stations, their Design and Arrangement.' The paper did not refer to the question of the machinery, it merely dealt with the buildings. For Mr. Wilson's information he would state that Bridlington had a permanent population of about 15,000, and a visiting population of about 25,000 extra in July and August. It was intended that there should be two engines of 160 H.P., and dynamos, and two Lancashire boilers, and the usual fittings of electricity works.

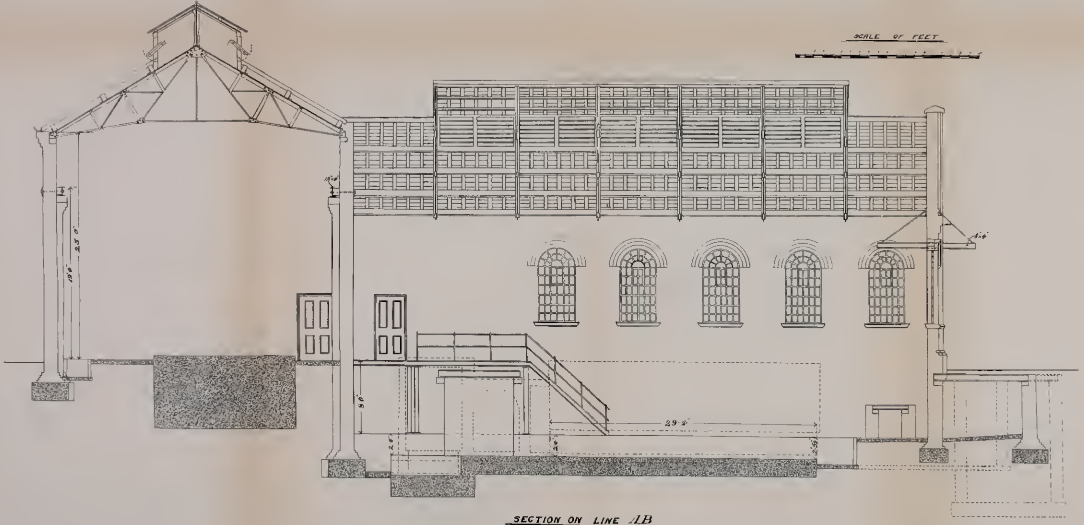
The cast-iron tank had been challenged by Mr. Wilson, and reference had been made to the Crystal Palace accident. If they were to be governed by accidents which occurred here and there, they would never erect a structure of any kind. No cast-iron tank was to be constructed at Bridlington, although he had mentioned that where a tank was to be constructed regard should be had to cast-iron plates; and he still thought that for small tanks such as were required at railway stations, cast iron was suitable, and that it was not much improved upon by either wrought iron or steel.

In the opinion of the President the use of plaster in the engine-house should be avoided, and the walls should be lined with glazed bricks throughout. It was his (Mr. Matthew's) intention to use glazed bricks throughout in the Bridlington engine-house, but for the sake of economy the committee wished the upper part of the walls to be plastered and colour-washed or painted.

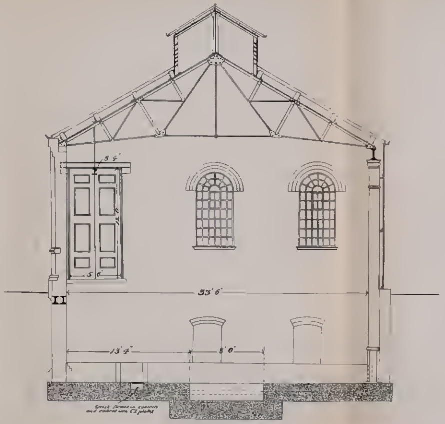
The use of armoured plate glass for the sky-lights, as suggested by the President, was an excellent idea, to prevent danger from the breaking of glass, and he should endeavour to introduce it at the Bridlington Electricity Works,

BOROUGH OF BRIDLINGTON

PROPOSED ELECTRIC LIGHT STATION



SECTION ON LINE AB



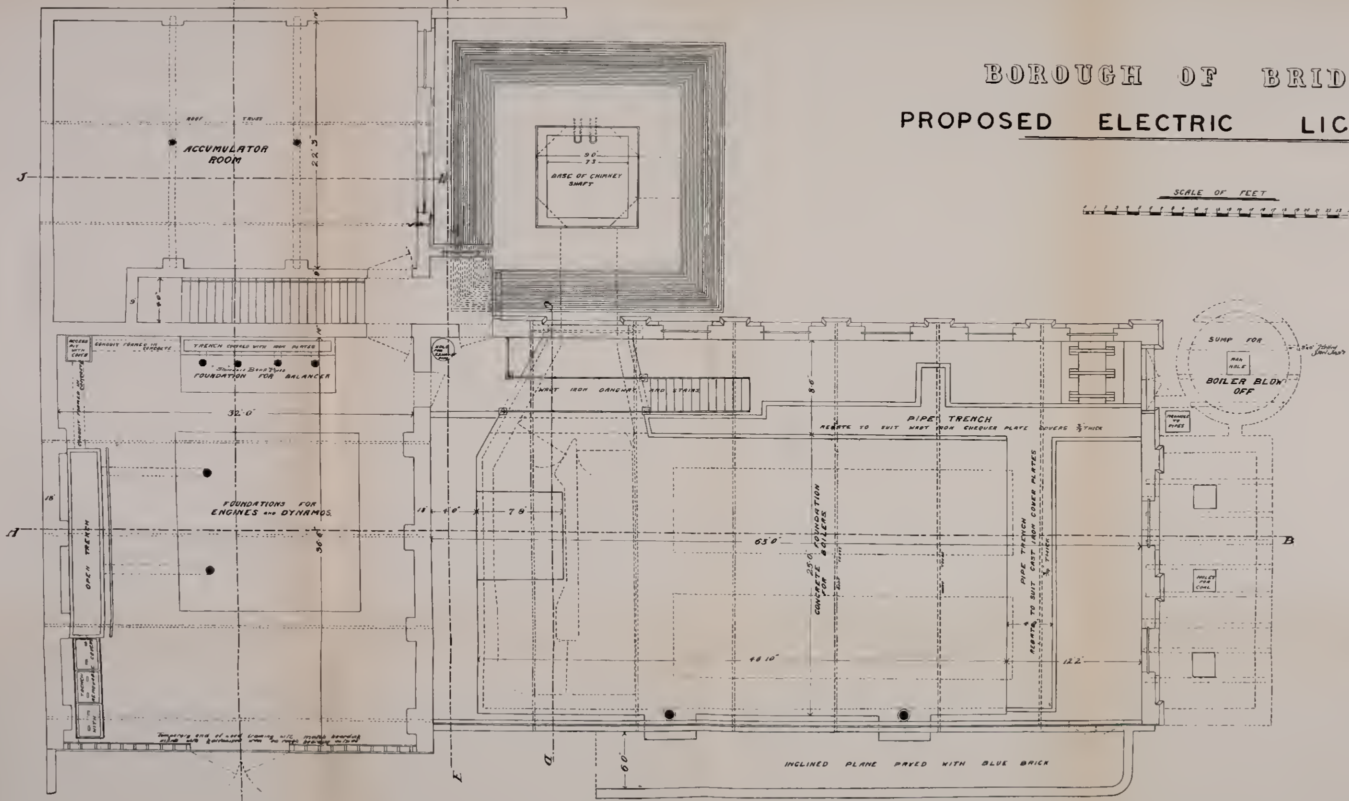
SECTION ON LINE CD

C.F.KELL & SON LITH 8 FURNIVAL ST HOLBORN E.C.

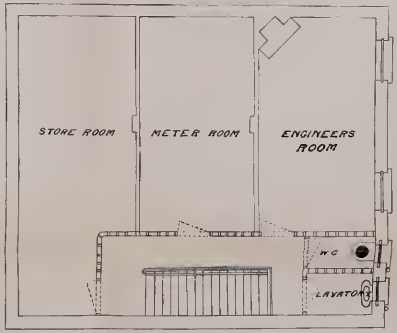
BOROUGH OF BRIDLINGTON

PROPOSED ELECTRIC LIGHT STATION

SCALE OF FEET


H
F
J
A
B
C
D
E
ROOF TRUSS
ACCUMULATOR ROOM
22'3"
9'
8'0"
BASE OF CHIMNEY SHAFT
9'0"
7'3"
ACCESS PIT WITH COVER
CONDUIT FORMED IN CONCRETE
TRENCH COVERED WITH IRON PLATES
FOUNDATION FOR BALANCER
32'0"
FOUNDATIONS FOR ENGINES AND DYNAMOS
OPEN TRENCH
30'6"
18'
1'6"
4'0"
7'6"
63'0"
WROT IRON GANGWAY AND STAIRS
PIPE TRENCH
REBATE TO SUIT WROT IRON CHEQUER PLATE COVERS ⅜" THICK
8'6"
25'0"
CONCRETE FOUNDATION FOR BOILERS
PIPE TRENCH
REBATE TO SUIT CAST IRON COVER PLATES ¾" THICK
46'10"
12'2"
SUMP FOR BOILER BLOW OFF
MAN HOLE
DRAINAGE TO PIPES
HOLES FOR COAL
6'0"
INCLINED PLANE PAVED WITH BLUE BRICK

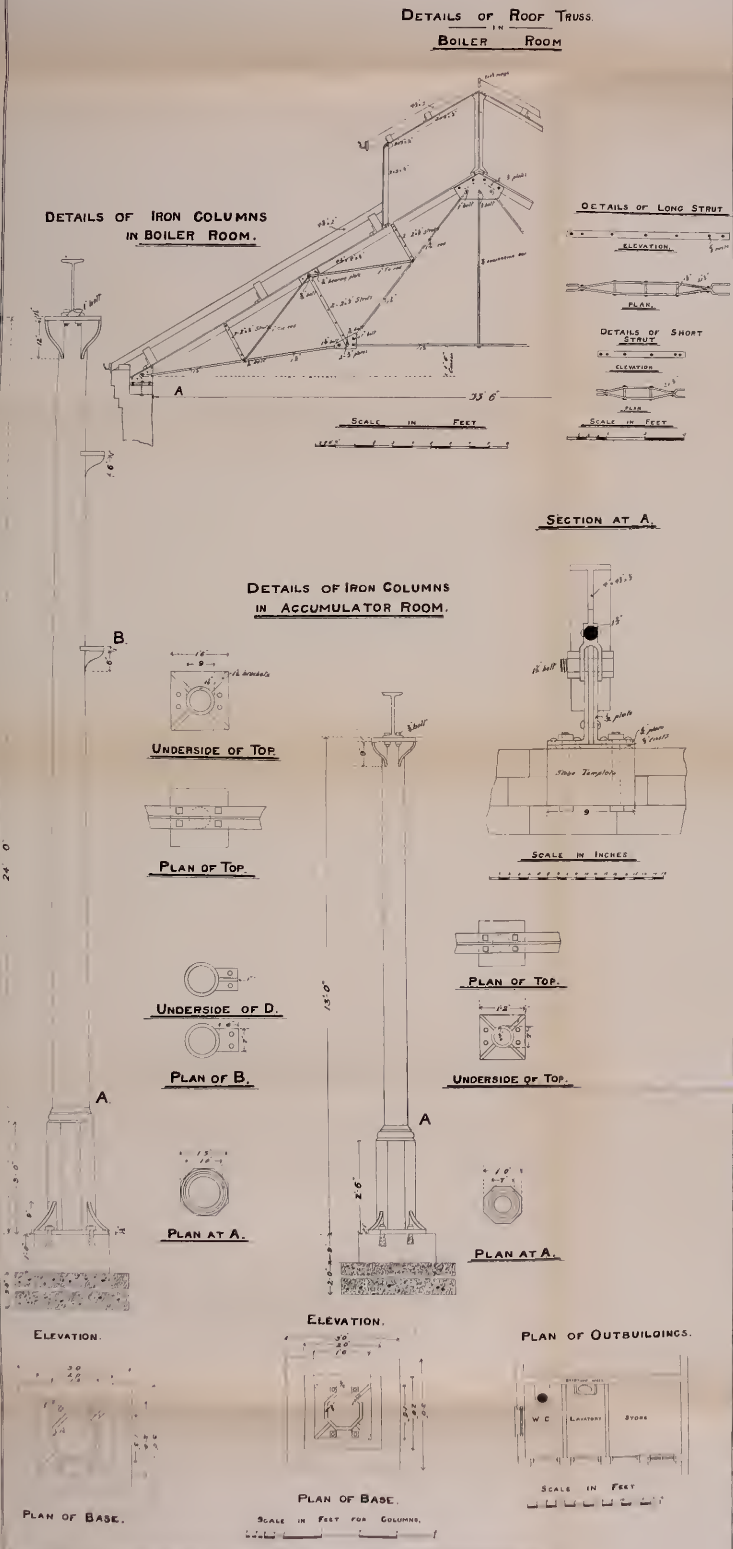
GROUND PLAN



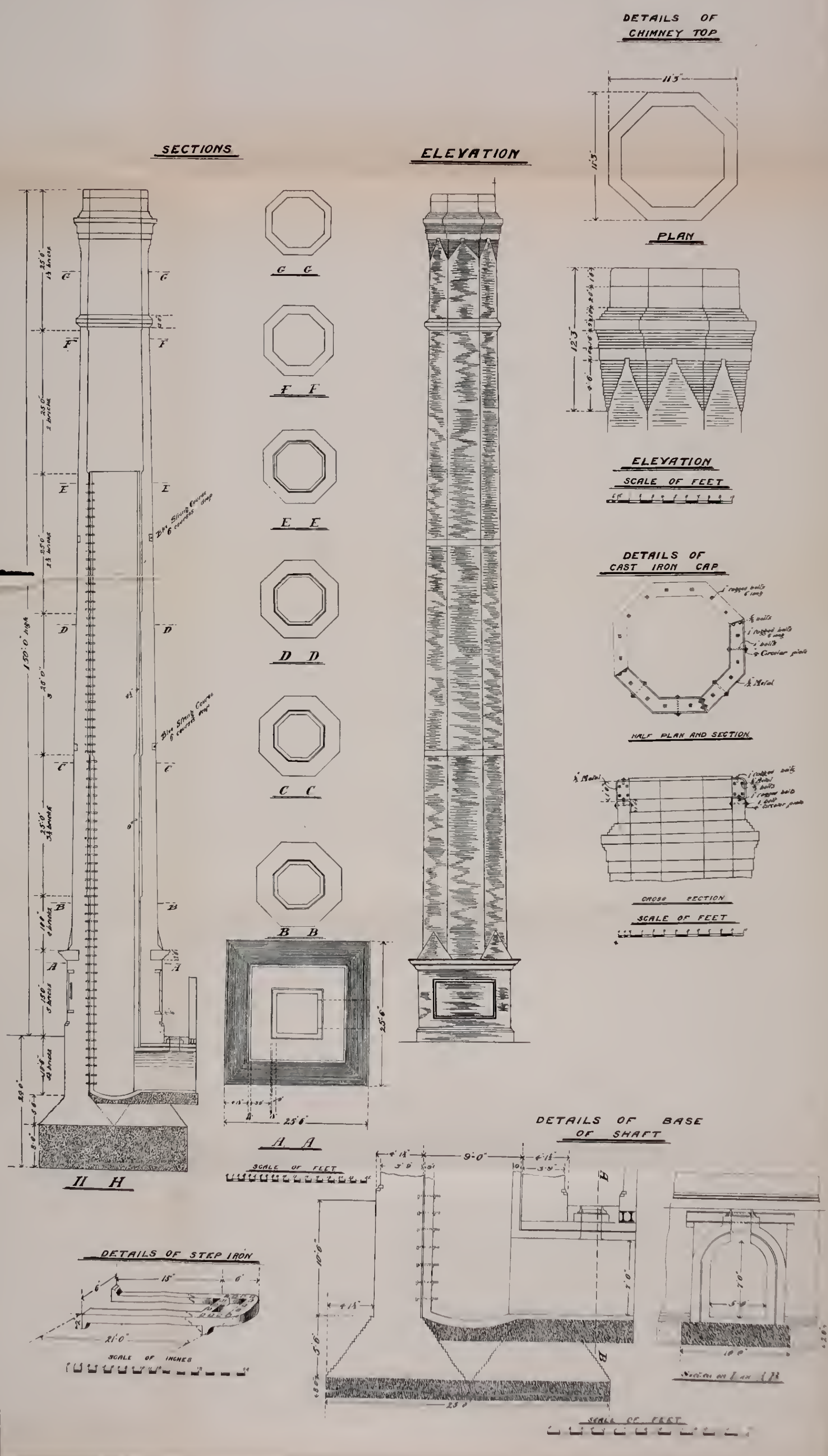
1ST FLOOR PLAN.

C F KELL & SON, LITH 8, FURNIVAL ST HOLBORN, E.C.

BOROUGH OF BRIDLINGTON
PROPOSED ELECTRIC LICHT STATION



BOROUGH OF BRIDLINGTON
PROPOSED ELECTRIC LIGHT STATION
DETAILS OF CHIMNEY SHAFT



G. F. Bell & Son, Lith. 9, Furnival St. Holborn E.C.

VACATION VISITS.

During the vacation of 1903, three visits were made to works of professional interest. The first of these, on June 24, was to the engineering works of J. & E. Hall, Limited, at Dartford, Kent, where the manufacture of ice-making and cold storage plant was witnessed, and a demonstration of the same was kindly given. The second visit was made on July 22, when the works of the New Admiralty Harbour at Dover were inspected by the kind permission, and under the guidance of Messrs. Coode, Son & Matthews, the engineers, and Messrs. S. Pearson & Son, Ltd., the contractors. The third and last visit was made on September 23, when the electricity generating station and the baths and wash-houses at Islington were inspected, by kind permission of the Islington Borough Council.

MESSRS. J. & E. HALL'S WORKS.

These works date from the year 1785, but during the last fifteen years they have been entirely rebuilt and fitted with modern machinery. About twenty-four years ago the company commenced the manufacture of refrigerating machines on the cold dry-air system, and in 1888 they took up the manufacture of refrigerating machines on the carbonic anhydride (CO_2) system, which was then entirely unknown in this country. Owing to the very much higher efficiency of the CO_2 system it almost entirely took the place of cold-air machines; and the manufacture of the CO_2 machines has so greatly increased that the whole works are now entirely devoted to the manufacture of those machines, with the exception of a few small cold-air machines for the Admiralty.

The CO_2 machines are made in some thirty or forty sizes and designs, belt-driven and steam-driven, and many of them specially designed for use on board ship. Owing to the high gas pressure at which these machines have to work their manufacture requires a very high class of both workmanship and materials, and an elaborate method of testing is carried out in the shops: thus every part of the machine which, when working, is subjected to the pressure of the CO_2 is tested, first by hydraulic pressure to 3000 lb. per square inch, and afterwards, when submerged in water, to an air pressure of 1350 lb. per square inch, the first test being for strength, and the second to ensure freedom from porosity. All parts after testing are stamped by the inspector, and erectors are forbidden to use any parts which do not bear a testing stamp.

The shops are driven throughout by electric motors, the current being generated in a power-house, principally by an inverted compound condensing engine and partly by gas engines, using producer gas. In the same power-house is the plant for generating the current for electric welding, and also the various air compressors and pumps required for testing purposes and for pneumatic work in the shops. The engine is driven by steam from Lancashire boilers fitted with Cass's automatic stokers. The power plant is about to be increased with a 150 K.W. direct steam-driven set, and a steam superheater is to be installed.

The pattern shop is fitted throughout with modern tools, the whole being electrically driven, mostly from below the floor. It is lighted throughout by electricity, and the electric current is also used for the glue-pots, thus avoiding as far as possible the risk of fire. The pattern stores are at one end of the building, and extend in one floor over the whole shop. The iron foundry is served by a 20-ton electric traveller, and another 10-ton traveller is about to be added.

The coil shop is devoted to the manufacture of iron coils for the condensers and evaporators of the machines, also to the manufacture of brine grids as used in cold stores and on board ship. In this shop, also, the various casings and tanks are made. For making the coils and grids the electric welding process is adopted, three welders being constantly at work for this purpose. An alternating current of 400 volts is used, this being transformed by stationary transformers in the machines to a current of 8 volts, 4000 amperes. The coils of various sizes are made on a special coiling table rotated by an engine. The pipe bends are made by a special hydraulic bender. Pneumatic riveting machinery is in use for riveting up the casings. For machines which are used on board ship, CO_2 condensers are made of copper coils, in order to resist the corrosive action of the sea water, and these coils are all made in the coppersmiths' shop They are tested in a similar manner to the other parts, subjected to the pressure of CO_2. The brass-finishers' shop is fitted with a number of special lathes of the turret type.

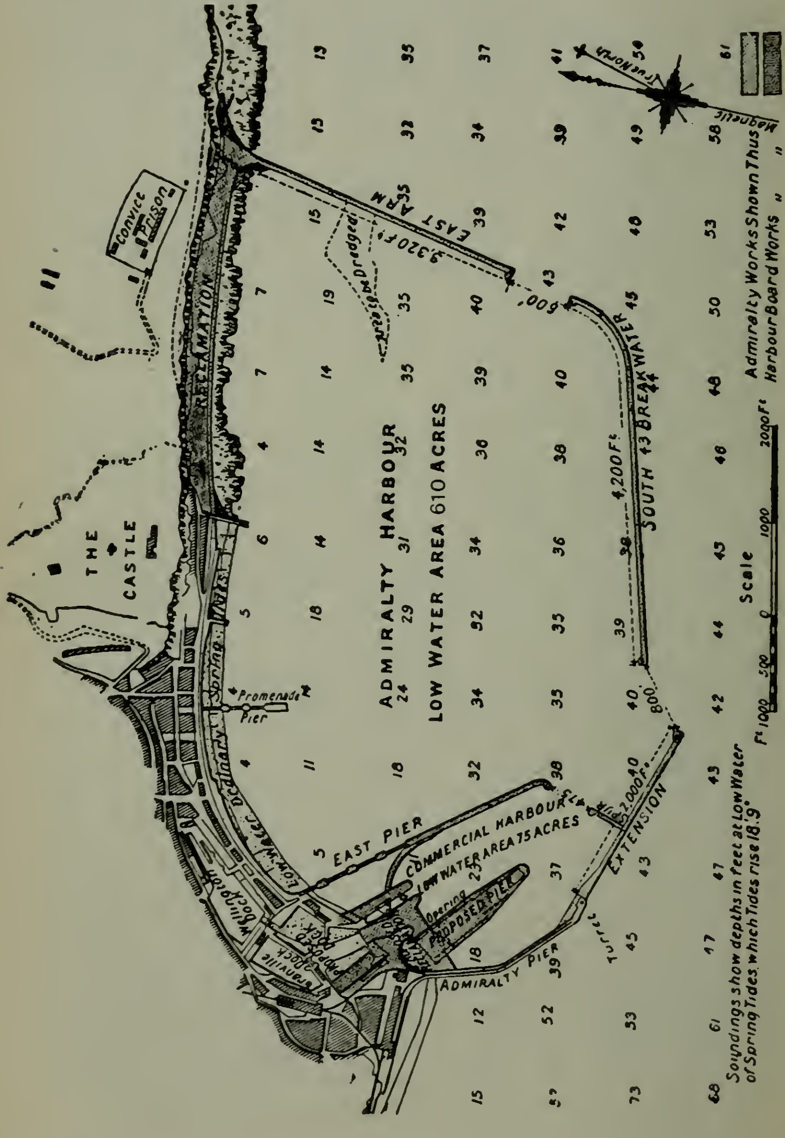
The tool stores are fitted with a few machines for making the special tools required in the shops. Use is made of limit gauges, and the metrical system is being gradually introduced throughout the shops. The machine shop is fitted with a variety of modern tools, driven throughout by electric motors.

Three bays of the erecting shop are devoted respectively to the erection of small, intermediate and large machines, and are commanded by 15-ton, 10-ton and 6-ton electric travellers. Arrangements are made so that in whatever position a machine is erected its tests can be run whether it is belt-driven or steam-driven. It is the practice to run all machines actually doing refrigerating work before they leave the shops. The amount of refrigerating work thus performed is measured, and a full record of the performance of each machine is kept. A machine was shown under test. It is stated that some fourteen or fifteen hundred refrigerating machines have been turned out at these works during the last few years, of powers ranging from small ones equivalent to the melting of 30 lb. of ice per hour, up to large ones equivalent to the melting of 12 tons of ice per hour.

The New Admiralty Harbour at Dover.

The following particulars of the works, and the accompanying plan of the new harbour, are taken from *The Engineer* of June 19, 1903. The map shows the shape and size the harbour will acquire when finished.

The nucleus of the present work is the old Admiralty Pier. Practically the history of the harbour dates from the year 1840, when a Royal Commission was appointed to survey the harbours on the south-east coast. This commission recommended the plan of a harbour at Dover, formed by a breakwater running practically parallel with the land, and at an average distance of 1000 yards from the shore, and by two arms projected from the land towards the eastern and western extremities of this breakwater. The estimated cost of the proposed works was 2,000,000*l.* Almost immediately after this commission had reported — namely, in the year 1844—another commission was appointed to report as to whether it was desirable that a harbour of refuge should be constructed in the Channel, and what site would be most eligible; having regard to accessibility, to its use if necessary for armed vessels, and to the facilities for defending itself which it possessed. This commission concurred in pronouncing a favourable opinion on Dover as a harbour of refuge. They were, however, uncertain as to the suitability of the ground for anchorage purposes, and raised the question as to the possibility of the harbour silting. The first point was put at rest by the emphatic testimony—as to the excellence of the ground, from an anchorage point of view—of Captain Washington, in command of H.M.S. 'Blazer.'



The New Admiralty Harbour at Dover.

With regard to the question of silt, a further commission, appointed in 1845 to consider plans submitted by eight of the leading engineers of the day, as to the form and construction of the harbour, reported that, "if liability to silt were deemed an objection it would be idle to attempt such works on any part of our coast." This commission practically confirmed the report of the 1844 commission as to the form of the proposed harbour. As a result, the contract for the Admiralty Pier was let in 1847. The structure was, save for a small addition to its seaward end, completed in 1871. Its total length is 2000 feet. Nothing further was done towards completing the harbour, however, in spite of the fact that in 1881 a committee appointed to report on the employment of convicts, suggested the building of a prison on the East Cliff and the employment of convict labour to build a pier and breakwater at Dover, so as to form with the Admiralty Pier a large harbour similar to that at Portland.

The Admiralty Pier afforded very fair protection against a south-westerly gale, but with a south-easterly gale the pier was exposed on both faces, with the result that serious delay and inconvenience was felt while these winds were blowing. Seeing that nothing was done by the Admiralty, the Dover Harbour Board decided in 1890 to construct a small harbour of their own, which work was sanctioned by Parliament in the following year. The work, which has been slightly modified by the later decision of the Admiralty to build the larger harbour, is shown in the plan, and is marked Commercial Harbour. The proposed pier, reclamation and lock, have not as yet been constructed, nor is the whole of the other work yet completed.

Towards the end of 1895 the Admiralty instructed Messrs. Coode, Son & Matthews to prepare plans for a large enclosed harbour. As a result the following recommendations were made. (1) That the Admiralty Pier should be extended 2000 feet in an east-south-easterly direction, practically doubling its length. (2) That an east arm, commencing a few hundred feet to the east of the eastern boundary wall of the convict prison, should be run in a direction approximately south by west for a distance of 3320 feet. (3) That an isolated breakwater, 4200 feet in length, should run generally west by south and east by north, but turning, towards the north at its eastern end, and should form the southern protecting arm. These recommendations are all shown on the accompanying plan. The average depth, at low water, of ordinary spring tides on the line of the southern breakwater is 42 feet. In addition, it was recommended to reclaim 21 acres of the foreshore. The suggested arrangement of breakwaters left an entrance of 600 feet in width between the east arm and the south breakwater, and an entrance 800 feet wide between the extended head of the Admiralty Pier and the south breakwater. Both entrances have a depth of about seven fathoms at low water of spring tides, which rise 18 feet 9 inches.

These proposals were accepted, and the contract for the construction of the harbour was let in 1897 to Messrs. S. Pearson and Son. The total length of the sheltering works to be constructed is 9520 feet; and the area enclosed, exclusive of the Commercial Harbour belonging to the Dover Harbour Board, will be 610 acres at low water, 322 acres being outside the five-fathom line and 171 acres outside the six-fathom line. The project put forward by the 1840 Commission embraced a harbour containing a total of 450 acres, of which 320 acres would have been seaward of the two-fathom line. We may here mention that the area of the Commercial Harbour, which was originally to be 56 acres, will, when the works are completed as altered, be 75 acres. It will be seen that the end of the Admiralty Pier Extension is some 400 feet to 500 feet south of the western end of the south breakwater. This arrangement has been made with the object of helping vessels entering the harbour when the tide is setting eastwards at its greatest velocity. At such times the speed of the current is nearly 4 knots. It will also be useful during south-westerly gales. At the present time the Admiralty Pier Extension and the east arm are nearing completion, and work is just about to be commenced on the southern breakwater.

In carrying out this important and interesting undertaking a temporary yard was first formed on the beach, in front of the South-Eastern Railway Company's town station. The blocks for the reclamation wall were built at Sandwich, where a large quantity of mixed sand and shingle was obtained. Originally these blocks were brought from Sandwich in lighters, but later on a light railway was built, by which they were delivered into the yard direct. Since the reclamation wall was finished, the area enclosed by it has been utilised as a block-making yard for the east arm and south breakwater, the ground having been made up by material scraped from the cliffs. Ballast, brought from Sandwich by the light railway, is lowered down on to electrically-worked gantries running on rails parallel with the cliffs. Cement is also lifted on to these gantries, and the process of making the concrete for the blocks for the east arm is carried on by means of mixers as the gantries move towards the block moulds.

For the construction of the masonry breakwaters, a grab, worked from a powerful goliath crane, removes all the loose material overlying the chalk. Another goliath manipulates an exceptionally large diving bell, by means of which the excavation and the levelling of the chalk bed are effected.

This part of the work is very heavy, as no block is allowed to be set at a less depth than 3 feet below the surface of the solid chalk. The weight of the concrete blocks employed is 40 tons each. Above water level they are faced with granite. They vary in weight from 10 to 40 tons, the latter being the size most frequently used. Below low water they are set without mortar, but are well bonded and keyed together by joggles inserted into recesses cored out at the time the blocks are moulded. About low water the blocks are set in Portland cement mortar, and are also keyed with joggles.

A magnificent harbour will undoubtedly be the final outcome of the present works. It will be sufficiently large to accommodate twenty first-class battleships, as well as numerous torpedo-boat destroyers, gunboats, and other vessels of smaller type. It should also prove of great utility as a harbour of refuge to merchant shipping in stress of weather. Berths for coaling purposes are to be provided for a length of 1800 feet along the inner side of the east arm. For this purpose it will be necessary to dredge the area enclosed by dotted lines, for it is intended that all along the inside of the arm there shall be a minimum depth at low water of spring tides of 30 feet. What is now the block yard will probably be used as a coal store.

The works are being executed under the direction of Major Sir Henry Pilkington, K.C.B., R.E., the civil engineer-in-chief appointed under the Naval Works Loan ; and of Messrs. Coode, Son and Matthews, the chief engineers by whom the design was prepared. The estimated cost of the whole work is about 3,500,000*l*.

The Islington Electricity Works.

These works are situate in Eden Grove, Holloway, at the side of the Great Northern Railway, and in a position that is practically the electrical centre of gravity of the borough. The system adopted for supply is high-tension alternating, with street tank transformers as sub-stations.

The works consist of a range of buildings comprising offices, new boiler house, double-bayed engine room, old boiler house, stores, workshops, and auxiliary plant room, yard and mains, workshops, and cooling tower. The offices have been arranged to come between the works and the Catholic church of the Sacred Heart, which lies south-east of the works and adjacent to it.

Coal is rail-borne, and delivered on a private siding from the Great Northern main line. The siding is continued through the works; and, by means of permanent ways over the coal bunkers in both boiler houses, railway wagons can be lifted and tipped directly into the bunkers, a special tipping gear being provided for the purpose.

The boiler bouses are excavated so that the firing floor is about 13 feet below ground level. They contain (old boiler house) four Babcock and eight Lancashire, and (new boiler house) six Babcock boilers, of the following sizes :—

Lancashire Boilers.

Diameter.	No. of Flues.	Grate area.	Normal Evaporation in lbs. Water atland from 212° F. per hour.
7 ft. 6 in.	2	33 sq. ft.	About 6000 lbs.

Babcock Boilers.

—	No. of Tubes.	Dia. of each Tube.	Heating Surface.	Grate Area.	Normal Evaporation in lbs. Water at and from 212° F. per hour.
		ins.	sq. ft.	sq. ft.	lbs.
(*a*) Nos. 1 and 2	72	4	1624	30½	5,500
(*b*) „ 11 and 12	81	4	1827	33½	6,500
(*c*) „ 17 to 22	252	4	5540	76	16,000

The steam pipes are arranged so that the boilers are coupled direct to the engines, and by means of an equalising range any boiler can be connected to any engine, or the whole system run together. By this means the large steam rings formerly favoured in electricity works have been avoided, and the condensation losses reduced.

The engines consist of the following: Wheellock cross-coupled compound, run at 95 revolutions, with a steam-chest pressure of 125 lb. to 150 lb. per square inch:—

No.	Horse Power.	Kilowatt Capacity of Alternator.	Maker of Alternator.	Method of Connection.
2	250	125	Fowler	Rope driven.
1	250	125	Fowler	Direct coupled.
1	250	125	Ferranti	„
3	500	300	Ferranti	„
3	1,000	600	Ferranti	„

There is also a combined engine-driven motor generator, consisting of Reavell high-speed 80 h.p. engine, Crompton 40 k.w. high pressure alternator, and Crompton 20 k.w. dynamo used for charging cells, and day plant.

The switchboard is situated on a gallery, which is extended across a portion of the width of the engine rooms at one end, and along the engine room down the centre, so as to command a view of every part. The high-tension machine board is a fourteen panel Ferranti 500 ampere board, split in halves, with the usual regulating gear instruments, fuses, and synchronisers. On either side are the circuit boards of the Fowler plug pattern; and on the extension gallery is the arc circuit switchboard, by Cowan's, Limited.

The alternators are run in parallel upon bus bars, and the rule adopted is that speed is adjusted for frequency, steam is adjusted for load, and excitation is adjusted for volts.

For street arc lighting there are five 30-light and three 50-light rectifiers, with two boards, one of the 1895 and one of the 1902 pattern, by Ferranti, and five alternating series, constant-current transformers. The street lighting now consists of 473 lamps, made up as follows: four circuits with a maximum of 30 lamps each, 12 amperes rectified; two circuits with a maximum of 50 lamps each, 10 amperes rectified; six circuits with a maximum of 30 lamps each, high-tension constant-pressure alternating with transformers in base of each lamp-post for the individual lamp ; four circuits with a maximum of 30 lamps, constant-current series alternating with compensators in the series circuit, and across which the lamps are connected. For side-street lighting, experiments have been made with the Reason Company's, the Improved Electric Glow Lamp Company's, and Nernst fittings.

The distributing system in the past has consisted of cast-iron pipes, containing double concentric rubber insulated steel-armoured cables as high-pressure feeders and distributors, also vulcanised india-rubber double concentric steel-armoured cables drawn into 3-inch earthenware pipes. Extensions are now being laid with paper insulated twin-arc cables, double-concentric paper insulated high-tension feeders, and triple-concentric paper insulated low-tension distributors, all laid on the solid system.

The meters in use are: Chamberlain and Hookham, Hummell, Guttmann, Westinghouse, British Thomson Houston, Aron, Stanley ; and Reason demand indicators are fitted where the sliding scale method of charging is adopted.

The Baths and Wash-Houses.

The Hornsey Road baths and wash-houses are the largest of the three establishments under the control of the Islington Borough Council. They were designed by Mr. A. Hessell Tiltman, F.R.I.B.A., and were opened in 1892; they were enlarged in 1899, and now consist of—

Men's 1st class swimming bath, 132 feet by 40 feet.
Men's 2nd class swimming bath, 100 feet by 35 feet.
Women's 1st class swimming bath, 75 feet by 25 feet.
Women's 2nd class swimming bath, 75 feet by 25 feet.
36 men's 1st class slipper baths.
72 men's 2nd class slipper baths.
10 women's 1st class slipper baths.
27 women's 2nd class slipper baths.

The public wash-house contains 49 washing troughs and 4 hydros, and is fitted with 50 drying horses heated by steam. Immediately adjoining the wash-houses is the mangling and ironing room. The establishment wash-house is fitted with one rotary washing machine and two hydros, the towels being dried in a room heated by steam. The whole of the fittings in the wash-houses and mangling and ironing rooms were manufactured and supplied by Messrs. Bradford and Co., of Manchester.

The water supplied to the swimming baths is heated on its way thereto by the injection of steam into the water main at two points. The original method of heating the water for the slipper baths has been abandoned, and it is now heated in two large cylinders by passing steam through pipes placed in the cylinders, the steam having first been used for heating the drying horses in the public wash-house. Steam can also be supplied direct from the boilers for heating the water in these cylinders.

A portion of the water used in the establishment is obtained from two boreholes in the engine room, each borehole being 13 inches in internal diameter and 450 feet deep, the first 215 feet in each boring being lined with ⅜-inch steel socketed tubes, the chalk being reached at a depth of 200 feet from the surface. The water has the characteristics of a greensand water, and is fit for drinking purposes; it rises in the boreholes to a height of 165 feet from the surface, and has a temperature of 55° F. The total yield from the boreholes is about 14,000 gallons of water per hour.

Pumps, 9 inches in internal diameter, are fixed in the boreholes, with the bottoms of the working barrels 270 feet from the surface, the pumps being worked by a pair of 10-inch by 20-inch Marshall's "K" class, horizontal, single-cylinder condensing engines, and may be worked singly if required.

The water is pumped through a 9-inch main to a tank over the establishment laundry, where it is heated by steam to about 70° F., the water then being delivered by gravitation where required. Water is also pumped through a 9-inch main to a tank over the board room, for use as cold supply to the slipper baths. At present there is insufficient storage capacity for the water required, so that the pumping is intermittent; the supply being supplemented by water obtained from the New River Company's main. A scheme for storing sufficient water for all purposes is under consideration by the council, and if adopted will enable the entire supply of water to be obtained from the boreholes.

The steam required for driving the engines and for heating purposes is obtained from two Lancashire and two Babcock and Wilcox boilers, all condensed steam being collected and used again in the boilers, with the exception of that from the engines, which is raised by an injector and discharged into the drains, as at present there is no means provided for removing the grease.

Electricity is used throughout for lighting the buildings, being generated by three dynamos manufactured by the Electric Construction Company, Wolverhampton. The steam for working the dynamos is also obtained from the before-mentioned boilers. The buildings are heated by means of hot-water pipes and radiators.

The entire cost of the buildings and equipment was 62,364*l.*, and since the opening they have been used by about 2,750,000 bathers and washers; the attendance for the year ending March, 1902, being about 280,000.

October 5th, 1903.

J. PATTEN BARBER, President, in the Chair.

MOTOR TRANSPORT FOR GOODS.*

By Douglas Mackenzie.

Introduction.

With the introduction of the Light Locomotives Act of 1896 a new field was opened for engineers in the construction of vehicles that could take advantage of the removal of the previous restrictions to mechanical traction. Whilst the number is legion of those who have devoted their energies to passenger vehicles, the number of those who have tackled the goods transport vehicles is comparatively limited. The firms who had had previous experience of mechanical transport on roads, namely, the traction-engine makers, seem to have agreed that no satisfactory engine could be constructed to carry a paying load and at the same time come within the limitations of the Light Locomotives Act. It was not until the Act had been in operation some time that three of the traction-engine makers produced light locomotives, and they were all of the young traction-engine type.

The fact is, that the stresses induced by road transport with heavy loads are so great that hitherto they had always been met by increased stiffness and weight, and when weight was to be kept down to a specified limit the problem assumed awkward proportions. Fortunately many other brains were prepared to boldly attack the problem, and, accumulating experience with every one made, they have gradually produced vehicles that are practical and useful machines.

The figures, however, that are available as to expenses of operating these motor-transport vehicles are either quite unreliable or are too indefinite to be of value to those who would wish to ascertain if motor wagons would be of service to them in their respective businesses, and, therefore, it is the author's endeavour to place before the members such experience and figures as will enable them to judge the field that now exists for motor transport.

It is necessary to explain that everything in this paper applies to the conditions in England alone, the author having no experience, and no means of obtaining reliable data, as to the success, or otherwise, of the many motor vehicles constructed in this country for use in India, Australia, South Africa, the Congo, and other countries. There, not only are climatic and road conditions different, but the legal restrictions and public prejudice are altogether different to those in England.

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* The President's gold medal was awarded to the author for this paper.

Legal Restrictions.

It is first necessary to briefly review the statute law relating to motor transport, and to consider the effect thereon of the passing of the Motor Car Act, 1903. The Locomotives on Highways Act, 1896 (better known as the Light Locomotives Act), and the Motor Car Act, 1903, are now to be known collectively as the Motor Car Acts, 1896 and 1903. Under these Acts a motor vehicle is negatively defined as (*a*) not exceeding three tons in weight, unladen; (*b*) not used to draw more than one vehicle; and (*c*) not emitting smoke or visible vapour, except from any temporary or accidental cause.

The Local Government Board have further enacted that, (*a*) the vehicle shall be capable of being propelled either backwards or forwards (vehicles weighing less than five cwt. do not come within the scope of this paper); (*b*) it shall not exceed six and a half feet in width; (*c*) it shall have two efficient brakes; (*d*) the tyres shall be smooth, and of certain specified widths.

The 1903 Act gives power to the Local Government Board to increase the maximum legal tare weights, subject to such regulations as to construction, use and speed as they may think proper or necessary. Under the 1903 Act, all motor vehicles must be registered and have a number plate affixed, and the drivers must each provide themselves with a licence. The regulations as to lights, gongs, reckless driving, stopping in case of accident, etc. are only reasonable, and require but passing mention.

One striking innovation of the 1903 Act is that it extends the application of both this and the 1896 Act to servants of the Crown. It is a principle of English law that statutes do not apply to Crown servants, unless it is specially so provided therein, and therefore the Post Office have hitherto had the power and the War Office have indulged in the practice of using motor vehicles exceeding three tons in weight unladen, and of travelling at much greater speeds than the ordinary public were permitted. Previous to 1896, all mechanically propelled road vehicles were under the Locomotives Acts, 1861 to 1878, and were limited in speed to 4 miles an hour in the country and 2 miles an hour in towns and villages, and required a man with a red flag in front as well as being subject to licensing enactments which are to this day a blot on English legislative ability.

There has also been a strong prejudice on the part of the horse-worshipping English against the traction engine, and to this day its use is hampered in every way that prejudice can suggest. Many local authorities, the Middlesex County Council to wit, have done everything in their power to keep traction engines out of their district, and if a progressive trader brings a traction engine into Middlesex, or Bolton (Lancs.), and many other places that could be named, he will find his engine watched by every surveyor and roadman to see what claims can be made out against him.

Various Types of Motor Goods Vehicles.

There being no field previous to 1896 for any mechanically propelled goods vehicles, other than the traction engine, many of the vehicles since produced have been quite experiments; but we can now, with six years' experience, see that several types have come to stay.

First there is the light delivery van, with an internal combustion engine, and not weighing more than one ton unladen. These are practically ordinary motor cars with the substitution of the van body for the passenger seats, and any improvement in motor car engines or design is equally applicable to these vans. They are fitted with the usual change speed gears and in most cases with rubber tyres.

Next, in point of size, are the heavier lorries, with internal combustion engines, weighing from one to two tons unladen, and capable of carrying two to three tons of paying load. Generally these are fitted with special bodies to suit individual trades, and a fair number are now in use.

The next type are steam lorries, weighing about two tons unladen, and carrying from two to three and a half tons of paying load. These are generally oil-fired, and have not power to pull a loaded trailer. They may be regarded as equivalent in capacity to an ordinary pair or three-horse lorry, though they will get over more ground in the same time than will the horse-drawn vehicle.

The next are the large size of steam motor wagons, weighing, when stripped to comply with the Act, three tons, and capable of carrying from three to seven tons of paying load, and pulling in addition from two to four tons on a trailer.

Lastly there is a special type of vehicle, which is most accurately described as a "young traction engine." It is practically a traction engine, lightened and reduced in dimensions to come under the Motor Car Acts, carrying no load itself, but capable of pulling from three to four and a half tons on a suitable trailer.

It is not the author's intention to go into the details of the design and construction of these vehicles (that would require a weighty volume), but rather to consider the economics of their employment, and to show where they can, and where they can not be profitably employed.

Sphere of useful Employment for each Type of Motor Vehicle.

In considering in what sphere each type of vehicle can be and is best employed, it must be remembered that evolution has not yet had time to weed out many of the experimental types, and therefore it is difficult to draw a hard-and-fast line between each class. Rather, one type merges into another, some intermediate in character, either of design or of function, joining them up.

The light delivery van is usually employed to deliver small parcels or packages within a limited radius, in London say within six miles, and in other towns say within four miles of headquarters. Consequently the driver only needs to know how to steer, regulate the engine, and to see that the automatic lubricators are filled up and working properly. Any adjustments or repairs can be carried out at the stables or at some convenient engineer's shop. The driver, though paid higher wages than the ordinary carman, is not as expensive as a fitter, and sees to the cleaning of his van. The motor delivery van is regarded as a good advertisement, a sign that the firm is up to date and pushing, and therefore has a value quite apart from its economy.

If the driver keeps his eye on the sight-feed lubricators and the petrol tank, the motor van never becomes tired, and can be worked longer hours than the horse, the driver generally being paid overtime. The motor van also gets over the ground quicker, but the calls are so frequent, and consume such a large proportion of the time, that a motor van will, in the same time, only get through about 5 per cent. more work than a horse. Any trader should know the cost of a horse delivery van, calculating interest and depreciation in horseflesh and van, horse fodder and bedding, wages, upkeep of van and harness, and rent of stabling. This varies very much in different places, and depends very much on the way the trader manages this department of his business. With the motor he must calculate interest on capital and depreciation, repairs and renewals, wages, petrol, lubricating oil, and rent of stabling.

Allowing that with longer hours and increased speed, the motor is able to do 25 per cent. more than the horse, the trader is entitled to reduce the charges against the motor, for the purposes of comparison, by 20 per cent. Even making this allowance, the author has not been able to hear of any case where the motor delivery van has been really an economical success. In cases where such has been suggested, he has found that no allowance had been made for interest and depreciation, or that some such error had crept in. By deducting the charges against the horse vehicle from those against the motor (reduced as aforesaid), the user can get at the cost of his advertisement, and he generally finds it a very expensive form of advertising.

The next type of vehicle is the motor lorry with internal combustion engine, which carries up to three tons of paying load. On the Continent it has been pushed in preference to the steam lorry, but it is not much in evidence here as yet. The author gathers from those who have them in use, that when a fair allowance is made for depreciation, interest on capital, and for repairs and renewals, they cost more per ton mile than do horses, but they can take a pair horse load considerably quicker, and on long runs of from 15 to 30 miles there is no necessity to stop for resting, as with horses.

They have another advantage, apart from economy, in that where goods would otherwise be sent by rail, delivery can be guaranteed. Goods when sent by rail have often to go over several systems, and then take from two to five days to travel 30 miles, so that though railway rates, even with cartage at both ends, may not cost as much as motor transport, yet the certainty of delivery may decide in favour of the motor. For their efficient employment on such work it is essential that the driver should be a skilled motor mechanic, capable of detecting at once from the beat of his engine anything that is not quite right, and of remedying it immediately. He will not always be close to his yard or stabling, as the light delivery van is, and may be miles from any engineer's, or a motor repair shop. Wages must therefore be high, and renewals a heavy item

The lighter steam lorries, carrying from two to three and a half tons of paying load, are generally oil-fired. The burners, however, require constant attention to keep them in order. If paraffin or kerosene is burnt, the cost of fuel is from 3¾*d.* to 6*d.* per mile run, which makes the cost of carrying cargo per ton mile very heavy, if not prohibitive. With the hydroleum burner, recently introduced for burning Texas residue, the cost can be reduced to 1*d.* or 2*d.* per mile. For the light loads carried by these lorries, the cost of coal or coke would work out to about the same. They would do a run of about 15 miles out and 15 miles back, and the cost of fuel per day may be put at five shillings. This is allowing for the fuel consumed in raising steam, and shunting about to load and unload. If paraffin is burnt, the fuel cost will be proportionately higher.

The boilers of these lighter lorries are necessarily so small that they must be either flash, semi-flash, or water-tube boilers. These all require very careful attention, and cost a great deal for upkeep, and a great deal of extra time has to be spent in keeping them in order. The makers generally give the cost of upkeep as very little, and it might be so with a perfect driver, but these are so rare that they may be left out of practical consideration. But, in addition to the boilers, very delicate boiler fittings are required for these lorries, and the frequent breakdowns due to trouble with the boiler fittings have led many users to give up these lorries. These vehicles really compete with the previous class, petrol lorries, and cost but little less to work. There is a field for them under special circumstances—for journeys of twenty miles and upwards—where not in competition with a direct straight railway service.

The better-known vehicles are the heavy steam lorries, burning coal or coke, and carrying from three to six tons on deck, and able to pull two-thirds as much again on a trailer. Many engineers, with very good reputations, have tried their hands at the design of these motors, and there are many excellent types now at work. The standing charges are so heavy that it does not pay to use them except with full loads. With light loads, or on very short journeys, they are only useful if special circumstances give them some peculiar advantage over other forms of transport.

Where users can make up loads of six tons and upwards it will be found that these motor lorries are more economical than horse haulage, as the terminal conditions will be the same in both cases; that is to say, the delays due to loading, unloading, getting clearance papers, and so forth. But the load must be all from one place and to one place. Stopping to pick up or set down part of the load affords the horses a much-needed rest, and enables them to pull much better afterwards. With the motor, however, it means a deadened fire and cooled cylinders, without any compensating advantage. Under such circumstances horse transport may prove the more economical.

If the journeys are twenty miles or more the motor vehicle would prove more economical than the horse with loads of four tons and upwards. For shorter journeys, of, say, ten or twelve miles, the critical load is five and a half tons. It must not be forgotten, however, that the railway rates will cut the motor out unless there are special circumstances, as already mentioned, so that on long journeys the motor has to compete with the railway as well as the horse.

Some of these steam lorries are a cross between the traction engine and the steam wagon proper. In these the boiler is of the locomotive type, and, as in the traction engine, forms part of the main frame. The only objection to this type, as a type, is, that viewed from the front, it resembles a traction engine, and so upsets the nerves of many horse drivers, and occasionally of the horses as well. Remembering the way in which traction engines are persecuted in Middlesex and elsewhere, the less the wagon resembles them the better.

There remains the "young traction engine" to review.

This form of motor has a special field of its own. None of the motor vehicles previously mentioned are to be trusted off the hard road. If they get too close to the side on a country road, either the wheels sink in and have to be jacked out, or they get bound in the softer ground, and the engine has not power to pull the loaded wagon out. Again, the wheels will not carry the loaded motor in a gravel pit, brickfield, or unmade road, even where traction engines could go. But the "young traction engine," weighing only four tons with coal and water, and carrying no share of the load, will float over a soft place that would bury a steam wagon, and it has sufficient power to pull its trailer through a soft place if the engine itself can get on firm ground. On the other hand, having less than three tons weight on its driving wheels, it has not sufficient adhesion to pull more than four and a half tons of paying load, as against the ten tons that the largest size of steam lorries can negotiate.

The designers have been unable to prevent the noise of the sharp exhaust at starting and the rattle of the gear, which are so objectionable in traction engines, and the unmechanical exhibit the same prejudice towards the "young traction engine" as towards its mother. The makers of these claim, with justice, that there is no need to wait to load and unload, and that the motor can be instantly uncoupled from a loaded trailer and coupled to an unloaded one for the return journey, or *vice versa.* There are many trades where this is a substantial advantage, and therefore there is a distinct field for the employment of this type. They are coming largely into use for market garden produce.

DIFFICULTIES OF MAINTENANCE.

It is essential that steam lorries should not be worked more than five days per week, and that they should be thoroughly overhauled on the sixth. Even then the cost of repairs and renewals would astonish those who have not gone into the question.

A severe tax is put on the boilers on account of their small dimensions. They are pressed to yield the utmost of their steaming capacity on steep hills, and this is often followed by long waits whilst loading or unloading. The author knows more than one lorry where the endurance of the boiler has been so severely taxed that it has been necessary to replace the boiler with a new one three times in as many years. The strains due to the uneven road surface play havoc with the joints on steam, exhaust and pump delivery pipes, and after nearly every journey there is some joint to re-make.

In gear-driven vehicles, there are, necessarily, many extra parts, to allow freedom to the hind axle, under the movement of the springs, whilst ensuring that the gear wheels are kept in mesh. This means so many extra parts to give trouble. On the other hand, the chain drive involves a greater risk. The strength of a chain is that of its weakest link, the wear is very rapid, and they soon get out of pitch. The life of a chain is very uncertain, but in hard work it cannot be taken to average more than eight months.

A good driver should be able to keep the engine and boiler in reliable condition, provided that he has proper help on the sixth day and at other times when necessary, so that he may repair and replace worn and injured parts. It is essential that some competent engineer should supervise the driver's work, and should constantly examine both boiler and engine, and should decide the best shape in which to effect the repairs. Allowance must, therefore, be made for supervision, in estimating costs, and additional fitter's labour must be included under the heading of repairs. At least four weeks in every year will be lost for extensive repairs, such as re-boring cylinders, re-tubing boiler, painting, etc.; but during this time fuel and wages will not run on. In estimating the cost of repairs, depreciation, interest, and insurance, the annual cost can only be spread over 240 working days.

Difficulties of Obtaining Accurate Working Costs.

It is necessary to emphasise the point that too many factors enter into the question of economical employment to make mathematical accuracy possible. With a stationary engine on a constant load, it is possible to measure the fuel consumption to three places of decimals, to work out $\theta\,\phi$ diagrams and to revel in squared paper, to talk of brake horse-power per pound of fuel, and to eliminate all personal elements. But with motor vehicles, the slipping due to a slight shower, or the obstinacy of a passing coster's donkey, may send up the fuel consumption, and five minutes' difference in the time of starting may so alter traffic conditions as to cause a delay of an hour in arriving. Consequently the questions of profitable employment have had to be answered by the information the author has accumulated from his own experience and that of others, and his opinions on these questions have necessarily been modified from time to time as fresh information came to hand, or fresh facts came to light, and will be further modified in the future as improvements are made in motor vehicles, and as road conditions alter.

It is necessary here to say a few words on the subject of depreciation. The ordinary system of writing off a fixed sum per annum may be very simple accountancy, but does not truly represent the actual value, from time to time, of the plant in question. The anomalies often seen of locomotives on the duplicate stock of our railways, long ago written off the books, but still earning a fair return, and on the other hand, machinery a year old, sold at half its cost, emphasise the error of this system of reckoning. This plan is particularly inapplicable to motor vehicles. Many makers say the life of their vehicles can be put at fifteen years; that would make the depreciation, on the usual reckoning, 6⅔ per cent. per annum. On the other hand, motor vehicles built three years ago have recently changed hands at a quarter of their cost price, which is equivalent to depreciation at 25 per cent. per annum.

Makers having now had more experience, the depreciation of a new motor vehicle should not be so heavy, but the change from new to second-hand, produced by about a year's use, takes a great deal off the selling value of anything, and any system of depreciation should show a large amount written off the first year, and a decreasing amount in each of the succeeding years. The author considers that the only fair way to calculate the depreciation of a modern motor vehicle by one of the best makers, is to write off 25 per cent. the first year, and to write off in each of the succeeding years 25 per cent. of the value as reduced by the deduction of the depreciation. With inferior makes a higher percentage will have to be taken. This results in an inverted compound interest system, that writes off a large sum the first year, but still shows that the scrap has some value even after fifteen years' use.

WORKING COSTS AND STANDING CHARGES.

Subject to the remarks already made as to the difficulty of arriving at the exact value of the working costs and standing charges, the author has endeavoured, from his actual experience,

Tabular Statement of Cost of Working Motor Lorries.

Tons per journey	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten
Capital cost of motor wagon	£500	£537	£575	£612	£650	£687	£725	£762	£800
Ton-miles per day	30	41	52	63	75	86	97	108	120
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Wages	0 7 6	0 8 5	0 9 4	0 10 3	0 11 3	0 12 2	0 13 1	0 14 0	0 15 0
Fuel	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 6	0 6 0	0 6 9	0 7 6
Stores, oil, etc.	0 1 6	0 1 6	0 1 6	0 1 6	0 1 6	0 1 8	0 1 10	0 2 0	0 2 3
Repairs and renewals	0 7 6	0 7 6	0 7 6	0 7 6	0 7 6	0 7 9	0 8 3	0 9 0	0 10 0
Supervision	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0
Interest on capital	0 2 1	0 2 3	0 2 5	0 2 7	0 2 9	0 2 10	0 3 0	0 3 2	0 3 4
Depreciation	0 10 5	0 11 2	0 11 11	0 12 9	0 13 6	0 14 4	0 15 1	0 15 10	0 16 8
Insurance	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1
TOTAL . . £	2 1 1	2 2 11	2 4 9	2 6 8	2 8 7	2 11 4	2 14 4	2 17 10	3 1 10
Cost of same work, with horses	1 0 0	1 7 6	1 15 0	2 2 6	2 10 0	2 17 6	3 5 0	3 12 6	4 0 0

and information kindly afforded by other users, to tabulate a statement of the average cost of working motor vehicles. In this table the cost has been worked out at per day, on the assumption that the motor is worked 240 days in the year, and that the working day is taken at ten hours.

Assuming, therefore, that one-third of the day will usually be occupied in loading and unloading, the ton-mileage is approximately arrived at, but it must not be forgotten how many indeterminate factors may affect this result. It is assumed that the return journeys will be made empty, or with empty bottles, boxes, casks or crates, so that the ton-miles can only be reckoned on the outward journey. If longer hours are worked, the fixed charges per ton-mile will be proportionately reduced, but the wages, fuel, stores, repairs and renewals, will always be proportionate to the ton-mileage for each size of wagon.

In the foregoing tabular statement, some items require a little explanation. It is presumed that the weight of the usual load being known, a motor will be bought designed to carry that load. If the load is under five tons, it is best to carry it all on the motor; if five tons or over, it is best to distribute it between the motor and a trailer, in the proportion of three to two. The cost of a trailer is therefore included with that of the wagon for loads of five tons and upwards.

The smaller vehicles can be worked with only one man, but an assistant is advisable in any case, and is a necessity with loads of five tons and over. The men will, of course, be employed on the Saturday, and perhaps at other times, in washing out the boiler, cleaning, overhauling and repairing. The wages, therefore, for the whole week must be divided over only five paying days. Interest at five per cent. is chargeable on the capital cost of the plant, and depreciation, as already explained, at twenty-five per cent. per annum. The depreciation gets less each year as the value of the plant decreases, but this is about counterbalanced by the increase in the cost of renewals.

It is very easy to lose sight of the small outgoings in repairs and renewals to lamps, suction hose, firing tools, brake fittings, etc. Experience proves that on an average one lamp per week is broken, though not always past repair. The author gathers all these together and includes them with repairs and renewals. It is assumed that the owner will insure his boiler, if a steam wagon, his men, against employers' liability, his wagon and trailer against fire, and his liability for third party damages. This, for the purpose of calculation, is taken at 25*l.* per annum per wagon and trailer. No allowance has been made for rent or office charges, as these would be much the same whatever form of transport is employed.

From these figures it will be seen that the minimum load for profitable working is about 5½ tons; but, as previously remarked, other considerations besides the comparison with horse haulage may have to be weighed. As in every business, the facilities for loading and unloading necessarily differ, the figures may have to be altered accordingly. Again, if return loads can be arranged, the cost per ton-mile can be halved, but the author's experience is that return loads, properly so called, not empties, can never be arranged in actual practice.

ENGINEERING PROBLEMS PRESENTED BY MOTOR TRANSPORT.

It is not within the province of this paper to discuss the various makes of motor lorries and their relative advantages and disadvantages, but motor transport still presents some very interesting problems for the solution of the mechanical engineer.

There are many debatable points that will only be settled on the Darwinian principle of the "survival of the fittest." These can merely be instanced in this paper, such as (*a*) three points of suspension versus four; (*b*) the type of boiler, locomotive, vertical fire-tube, water-tube, flash, semi-flash, or hybrids; (*c*) gear versus chain transmission; (*d*) spring driving; (*e*) the method of transmitting the tractive effort to the main frame. There are, however, two points which call for more detailed discussion, namely (A) road wheels, and (B) heavy oil motors.

No wheel has yet been made that will stand for long the effect of motor transport. Wooden wheels, after a month's work, begin to open at the felloes, and though constantly tightened up at the hub they require to be replaced or entirely reconstructed after 18 months' work. Built up steel wheels are used with either cast or forged hubs and spokes riveted to the rims, which are made of angle or tee irons. Wheels have also been tried with some success, made of two dished plates, with portions cut out to lighten them. All steel wheels require some form of tyre riveted to them, and it is only by constant attention to the rivets that these wheels are kept running.

The author has noticed that one firm of makers is now sending out wheels made like steam roller wheels, with cast hubs and rims, cast with the spokes in position. These are excellent whilst they last, but a broken spoke cannot be replaced and cannot be satisfactorily patched. Some motor lorries have recently been supplied to the War Office with cast steel wheels, the spokes being cast with the boss and rim, and these are run in the first instance without tyres. It remains to be seen how the spokes will stand the road work.

On paved streets the slipping of smooth-shod wheels, which have to propel the vehicle as well as carry the load, is very dangerous. The author has observed a motor-wagon on a granite paved London street swing round through an angle of 180 degrees, by the slipping of the driving wheels. It can well be conceived how dangerous this is in crowded traffic. Therefore when the ideal wheel is made it must have a tread that will not slip and yet will cause no more resistance to motion than does a smooth steel tyre. The author hopes to carry out some extensive experiments in this direction, and would always be pleased to afford opportunities for the trial of new wheels and tyres on his motor-wagons.

As regards heavy oil motors, there are so many advantages for motor work attached to the internal combustion engine, especially with the lighter loads, that it is only the cost of the spirit that militates against their use. There are obvious advantages in being able to start at any time, and not having to stop to raise steam. Consequently every one conversant with the needs of motor transport is looking for an internal combustion engine that will work with crude heavy oil instead of the expensive petrol. The success of the Hornsby and Diesel engines for stationary work shows that we are within a measurable distance of attaining our wish, but at the present time there is but one such motor on the market for road traction, and that does not appear to have emerged from the experimental state. Texas residue can be bought in bulk on the wharf at forty shillings per ton, which works out to twopence per gallon. If this is compared with the cost of petrol it will at once be seen what an enormous impetus motor transport would receive on the production of a practical and efficient internal combustion engine that would work on this oil and stand the trying conditions of road work.

New Regulations under the 1903 Act.

The public will now await with some anxiety the regulations which the Local Government Board are empowered to make under the new Act. It is to be hoped, in the first place, that the maximum tare weight of motor vehicles will be raised to six tons, and that, in addition, a trailer of two tons tare will be permitted. With such a tare weight much more reliable vehicles could be made, as strength would not have to be sacrificed to lightness so ruthlessly. This would both reduce the liability to breakdown and the cost of upkeep. There would not be a proportionate increase in the weight carried, as the number of firms who require to send out over ten tons at a time to any one place is very few.

Elaborate and careful statistics as to the weight of consignments by rail shows that the average for the whole country is about 2 tons 7¾ cwts. This is evidence that few firms make such very weighty consignments. Further, a great deal of the opposition of the coal merchants of this country to the introduction of the large-capacity railway truck is probably due to the fact that 10 tons is as much as even a coal merchant requires at one time of any one coal. In fact hardly anyone is prepared to deal with larger consignments of anything than 10 tons, and, therefore, that is likely to be the maximum consignment, no matter how lenient the regulations may be, but the extra tare weight is requisite to enable a more lasting and more reliable machine to be manufactured.

There is absolutely no necessity for any regulations as to the speed at which such heavy motor wagons may travel. They are never wanted to travel at a greater speed than that of the loaded pair-horse van, and no maker or user would try to run them faster. On the other hand, when returning empty there is no justification for limiting them to five miles an hour, as if travelling at eight miles an hour they would be less obstruction on the road and they would be more under control than any horse-drawn vehicle.

It is not only reasonable but necessary that such regulations should make obligatory a much wider tyre than that specified under the present regulations, and a larger diameter of wheel should also be made obligatory. The present motor wagons can never be trusted off the very hardest roads. The actual gross weight may not bear comparison with that of traction engines, but the concentrated pressure is greater, being carried on a much narrower wheel and one of much smaller diameter.

Wear and Tear of Roads under Motor Transport.

No statute, except section 28 of the 1878 Act, has hitherto dealt with the diameters of wheels for heavy traffic, and the subject has never received proper consideration. The author has often noticed on a road that would be considered fairly hard the road actually bends under traction engine traffic, and the engine or wagon wheel may be seen to be taking a bearing for a length of from 18 inches to 2 feet, or even more, the road springing up again after the wagon has passed. Under constant traffic of this nature, a flint, gravel, or limestone road is soon reduced to mud or dust, according to the weather, not by abrasion of the surface, as with ordinary horse traction, but by crushing and abrasion of one stone against another, as this concentrated load is applied and removed. Further, when the road yields thus, there is a shearing action at the edge of the tyre that helps to destroy the surface of the road. If there is no foundation, the wheels shear right through, and the wagon has to be jacked out. An increase of the width of the tyre would reduce this effect, but an increase of diameter would produce a much greater effect.

A year ago, having a traction engine working on a weak gravel road, the author made some careful measurements of the amount to which the wheels depressed the road. The engine weighed with coal and water 16 tons, of which 14 tons was carried on the driving wheels. These were 1 foot 6 inches wide, and 7 feet in diameter. Each wagon with its load weighed 12 tons, of which 6 tons was carried by each axle. The wagon wheels were 9 inches wide, and 3 feet 6 inches and 4 feet diameter respectively. At the first place measured, the engine depressed the road ½ an inch, and each truck wheel 1½ inches. In another place the engine depressed the road 1 inch, and the truck wheels 3 inches. The pressure per inch width of tyre was respectively ·39 tons and ·33 tons. From this it will be obvious that the diameter has more effect than the width in preventing road damage.

Many county and district surveyors have, in conversation with the author, spoken of the destructive effect of repeated motor traffic on weak roads. There is a very simple remedy for this, namely, to make all the roads decently strong. Unless there is both a thoroughly good foundation to the road, and also a really hard surface, this traffic soon shows effects. As no motor wagon will pull through bad roads, either the driver finds another road round and proceeds to cut that up, or the owner lays stone on the road with no regard to the principles of road construction, or of the results to any traffic but his own. More frequently the owner, who having his mill or factory in the village is one of the largest ratepayers, brings pressure on the council to make up the road to a proper standard.

There is no doubt, however, that roads have to carry greater weights every day, and as these wagons have come to stay, all roads ought, as soon as is financially possible, to be made up to a proper standard. It is a disgrace to any district in this twentieth century to have a public road that is not strong enough to carry motor wagon or traction engine traffic. It is only fair to point out that if the road is made up to a proper standard, with a good foundation and hard crust, the wear produced by motor transport is less than with any other form of road locomotion. The hammering action of the horses' shoes is entirely absent, and the tearing action of the traction engine driving wheels, pulling at the road to get a grip to draw forty tons behind it, is replaced by the rolling motion of the smooth motor wheels, which help to consolidate the road surface, and produce no abrasive action. Motor users are therefore justified in demanding hard well-made roads, urging with accuracy that the capital expenditure in thus making up the roads is more than counterbalanced by the reduction in upkeep.

SUMMARY.

In summing up, it will be useful to look at the advantages of motor transport from the point of view of various users.

For small traders or retailers, or for those whose goods are sold in comparatively small parcels, the motor vehicle offers no economy, but is occasionally used as an advertisement.

For manufacturers whose goods are sent out in two to three ton loads the motor vehicle offers a mode of transport that is quicker, though not more economical, than horses, and which offers a more certain delivery than rail.

A large contractor would find one or two motor wagons very useful for weighty materials, but would have to bear in mind its several limitations. For instance, many goods are sent by barge up the Thames, and discharged overside at low water into carts standing on the shingly river bottom. No motor wagon yet constructed would pull a paying load from such a situation, and up the steep slopes on to the road.

A road contractor, again, would find that the motor wagon can do but little of his work, as except in a very dry summer, it could not be trusted into gravel pits, brickyards, or on to unmade roads, whilst it has not the power to pull over a rough ballasted road, where it would often be required to deliver its load.

Many steam wagons are now at work for brewing firms, and seem well suited to their needs. But mineral water manufacturers can very rarely make up large enough consignments to single customers. Motor wagons have been tried for rounds work, but so much time is lost delivering small quantities and hunting up empties, that a motor wagon cannot deliver more in a working day (and the mineral water carter's working day is not far short of twenty-four hours) than could be handled by a pair of horses.

Flour is a very heavy material and handled in large parcels, and several motor wagons are now engaged in this work. Cement is sometimes sent out in large enough parcels to justify the use of motor wagons, but so much is sold a sack or two at a time, that it is difficult to keep the motor wagon in constant work.

Without specifying the materials, it may safely be said that with heavy loads, 5 to 10 tons, and short runs of 2 to 4 miles, the question of whether motor transport is more economical than horse transport entirely depends on whether the loading and unloading can be carried out with sufficient expedition. On the other hand, with light loads of from 2 to 3 tons, and long runs of from 15 to 30 miles, the question of economy turns on whether there is competition with railway rates. For such loads the motor should be one of light tare, constructed for the loads in question, and able to run at a fair speed.

The ideal work for motor transport is where loads of from 5 to 10 tons require to be constantly carried for 10 or more miles. The word "constantly" is used advisedly, as the wagon body should be constructed specially to suit the particular trade, as taking a load of, say casks, on a body constructed for boxes, or broken granite on a flat platform lorry, is both costly and destructive.

For municipal work there are very few circumstances under which the motor wagon can be used to advantage. For dust collecting an intelligent shire horse requires no more attention than an occasional word from one of the men, but if a motor is used an expensive driver must be employed to drive it from door to door. Again, street, market or house refuse all bulks large, and it is impossible to get more on a motor wagon than two horses would take at the trot. Further, the runs are mostly short. For street watering the distance between hydrants is short, so that there is no advantage in being able to take more than a horse would pull. In Liverpool and Westminster the motor wagons are worked twenty-four hours a day, but the author believes that, making proper allowance for depreciation, and charging correctly all repairs and wages, the work could be done cheaper and as efficiently by horses.

Many firms who have tried motor vehicles have given up their use from various causes. In some cases the loads and journeys were not such that a motor wagon could be used to advantage. In many cases, however, the constant attention they require and the close professional supervision, or, failing this, the frequent breakdowns, have led to their rejection.

It would therefore seem that the better system is to contract with a firm to do the cartage required, with motor wagons. Many manufacturers put all their carting out to contract, and find it the more satisfactory method. It is reasonable to suppose that an engineering firm, with its proper staff of overseers and foremen, and its own repairing workshops, would have a much better chance of conducting motor traffic with economy and dispatch. At the same time the trader would be relieved of this extraneous responsibility, and would be enabled to devote all his energies to the prosecution of his own legitimate business.

The author trusts that his views on the subject of motor transport will not be considered too pessimistic. He has endeavoured to set forth dispassionately the economic position of motor vehicles. The progress of mechanical science is constantly changing the economic conditions, and the circumstances of to-morrow may be widely different from the circumstances of to-day. Better engines, cheaper fuel, less legal restrictions, and the accumulating experience of engineers, will rapidly increase the range of useful employment for motor vehicles. No one regrets more than the author that motor transport is not, as some seem to think, the solution of all our social, moral, political, hygienic and economical difficulties.

DISCUSSION.

The PRESIDENT said that he had very great pleasure in asking the meeting to pass a very hearty vote of thanks to Mr. Douglas Mackenzie for the very useful paper which he had read. It was an advantage to have a paper read by someone who knew from practical experience the difficulties and the cost of working motor vehicles for business purposes. They were very much obliged to Mr. Mackenzie for the trouble he had taken in preparing his excellent paper.

The vote of thanks was accorded unanimously.

Mr. R. H. GRIFFITH said that although Mr. Mackenzie had written a very interesting paper, he could not find in it any statement of the cost of horse-traction for comparison with the cost of motor traction. As regarded the "young traction-engine," he thought that it might be a very useful sort of animal, but as it was constructed at present there was too much vibration, and he should imagine that the driver of it would suffer physically after about six months' use of it. The break-downs could be and ought to be overcome.

The points which Mr. Mackenzie had mentioned all showed clearly that motors as now made were not heavy enough, or that if they were heavy they had not good engineering in them. If they were made strong enough to stand the heavy work put upon them and the changes of surface in the roads, the present difficulties would be got over, and he felt that it was only a matter of a very short time before that was done. It was only six years since the law had allowed motors to be used on roads. He knew some which were running very well without being under engineering supervision. That was what was wanted. If a man had a horse he could not always have a veterinary surgeon looking after him. The inconvenience of breakdowns could be overcome to a large extent by the users of motors keeping spare parts in stock, but he did not think that any user would be justified in laying in a good stock of spare parts.

His experience was that motors would pay for working rounds, and calling at different places and making several stops during the day, with 2-ton and 3-ton loads. He found that when they went successfully without breaking down they would accomplish long journeys two or three hours earlier than they were performed by horse traction. But he thought that a fifteen years' life which Mr. Mackenzie had suggested was greater than any motor would have at present. He should say that five years would be the limit.

He had used several motors and had kept records, and he had found that in some weeks they cost 3*s.* per ton mile and sometimes they had got down to 2¾*d.* He was satisfied that in a year or two motors would prove much cheaper than horses. There were expenses in connection with horses which stablekeepers did not acknowledge.

Mr. H. Sherley-Price said that he did not know very much about the subject, but it had occurred to him as rather strange that the author had made no reference whatever to motors driven by accumulators. Perhaps he thought that they were out of the question. Undoubtedly, in our present state of invention, they were out of the question for heavy traffic, but he did not see why they should be for light traffic. It seemed to him that the use of accumulators might be a matter of arrangement. He did not think that it would pay any single individual to have one, two, or even a dozen small vehicles driven by accumulators, and to do his own charging. But a central station might be used for charging light cars, in the same way that a central station was used for charging electric cabs. Electric cabs were becoming more numerous in London daily, and they were worked very economically. People in London could hire them at rates which worked out at less than half the cost of those in the suburbs. In the suburbs a special charging station would have to be erected. If he wanted to charge the cab himself he should have to put down a dynamo and batteries, and a gas engine and all the rest of the paraphernalia, and also engage an electrician. So it would be with small electric motor cars or parcel cars. But he did not see why accumulators should not be used if a number of cars were working together. He wondered why accumulators had found no place in Mr. Mackenzie's admirable paper. There was no doubt that that form of transport had "come to stay," and he believed, that like "the fiscal question," it was the question of the hour. Some firms were turning out about fifty wagons a year, costing probably 800*l.* to 1000*l.* each. Therefore there must be a big demand somewhere.

Mr. A. M. BELL said that he had to look into the subject of Mr. Mackenzie's interesting paper about fifteen months ago, when his firm undertook delivery by motor wagons. His first experiences were certainly not very good. The experiments, however, convinced him that, whilst it would be impossible to work one single steam lorry and compete successfully with horse traction, the regular operation of a number, with a certain minimum load, was far cheaper than the latter power. He had very complete figures for the horses, seeing that he hired them by the day and he knew exactly the cost of delivery per ton.

As to the "young traction engine," it appeared to be a very favourable machine, but he thought that it would not have sufficient adhesion for service in the streets of London.

As to the most suitable boiler, he first tried a water-tube boiler fired with light oil, using a vaporising burner, but the tubes could not be depended upon, and the burner was a constant source of trouble; and he was convinced that the best boilers for the work were those with fire tubes, and using coke or heavy oil as fuel. One point which suggested itself with regard to the water-tube boiler was, that it might be made in two distinct portions, so that in case of one half of the boiler failing the other half would be available to work the motor home. The quantity of dirt accumulating in the boiler was very considerable, and it was essential that it should be cleared out every week.

With regard to heavy oil motors, it seemed strange that makers at the present time kept to petrol, the cost of which was certainly prohibitive. Spirit of a higher specific gravity was available, and there appeared no good reason why it should not be made use of. At present, builders were only making motors to work with petrol.

As to Mr. Mackenzie's hope that a still cheaper oil-fuel might be used in the internal combustion engine, that seemed to be difficult in small motors. It seemed to him (the speaker) that the cylinders for such would have to be so limited in size that they would require very frequent cleaning; and the question was whether such oil could be utilised at all, although some means of getting over the difficulty might yet be found.

He thought that the greatest point in Mr. Mackenzie's paper was the last paragraph. If motors were worked from a head depot, where there was engineering help, and where there existed proper facilities for cleaning and for general superintendence and for examination, after each journey, the probability would be that motor traffic would become very satisfactory in the long run. He knew several instances in which motors were used to convey goods more cheaply than railway carriage, because railway carriage involved cartage after the goods had reached the station. By means of motor transport he could make deliveries of suitable tonnage from the depot in London to the consumer in the country at a less cost per ton than by rail.

Mr. ARTHUR RIGG said that the paper was a commercial rather than an engineering one, and there was not much to be said upon it from an engineer's point of view. He had seen many motors at shows, but, so far as the engineering design of them was concerned, they seemed to him to be in many cases admirable patterns of what to avoid. They contained many clumsy and imperfect arrangements, and it was not surprising if constant breakdowns took place and that the cost of repairs appeared to be rather heavy.

Most of the boilers which he had seen were badly designed, inasmuch as they were so arranged that sediment settled at the bottom of the tubes, and if the fire was very hot the tube was burned. He could not understand why the Corliss boiler was not used. The Corliss engine was very well known in this country, but the Corliss boiler was not. It was an admirable boiler, and more suitable for steam cars than any other boiler that he had seen.

Another point which he should like to refer to was that of the fuel. They had all heard of the Mond gas. With that fuel care was taken that all the tar was converted into gas. That was what they wanted to do with crude petroleum. It was a question of chemistry rather than engineering, and what could be done with tar could surely be done with petroleum.

Mr. J. BERNAYS said that although the paper did not deal with a question that appealed directly to engineers, it gave to those who were likely to use motor wagons a very good idea of what they had to look to. He was at the present time erecting a large works in the neighbourhood of London, and his clients were considering whether they should use motor wagons instead of the railway for the carriage of their goods to London and the neighbouring towns. If the railway was used in this case, a siding of a somewhat costly description would have to be made to bring the railway to the factory. In looking through the paper he found a great many ideas which would help them to come to a decision. For instance, in speaking of the question of whether horses or the motor wagon should be used, the author said, "The load must be all from one place to one place. Stopping to pick up or set down part of the load affords the horses a much needed rest and enables them to pull much better afterwards. With the motor, however, it means a deadened fire and cooled cylinders without any compensating advantage." That was a point which was very useful when once stated, but it might not occur to everybody. It meant that if stoppages were to be made at various places, the use of the motor car might not be economical.

He did not think that Mr. Mackenzie meant to be pessimistic with regard to motor cars, he had only brought forward the various points both for and against them which ought to be considered.

He did not know much of the details of motor cars, but it had struck him long since that steam was not the most economical power for them. They had to deal with very rough roads as well as with crowded streets, and he was rather of opinion that ordinary gas might yet be capable of practical use for motor wagons. He did not mean that they should carry compressed gas in cylinders, but engineers might one day be able to get a raw material from which gas could be manufactured at the moment that it was required, just as acetylene was manufactured from carbide. In the case of the latter the raw material was easily carried without danger, and without great bulk or weight.

In considering the quality of the work and the design of motor cars it must not be forgotten that the manufacture of such vehicles was of very recent date. It was not more than five years old. It would be remembered that railway locomotives in their early days were worked with chains and wheels and all sorts of contrivances, just as motor cars were worked now. He had no doubt that when the manufacture of motor cars had reached its manhood, the cars would be driven in the same simple way as locomotives were driven now; and he was equally sanguine that manufacturers would succeed in producing gas engines which could be started and stopped at any moment.

The tabular statement in the paper was very interesting, but there was no indication on the table itself to show that it represented the cost per day of working the lorries. He would suggest that Mr. Mackenzie should make the table clear with regard to that point.

Again, it would be very useful if the horse-power of the various motor cars could be given. The author spoke simply of "light" and "heavy" cars. A statement as to the average horse-power of the main divisions of cars would be desirable.

Mr. MAURICE WILSON said that he had been particularly interested in the author's reference to the "young traction engine," for he had lately had to do with such an engine.

During the last few weeks two wealthy and charitably disposed ladies had placed a "young traction engine," called "The Little Giant," at Sydenham, near the Crystal Palace, for the purpose of drawing heavily loaded vehicles up any of the steep hills in the neighbourhood. The engine would drag up the vehicle, the horse, the driver, and everything, free of charge. That was, he believed, the first experiment in that direction that had been made. The service was rendered with the idea of saving the horses. Whether the privilege was likely to be abused was a matter of opinion. Of course, under the peculiar circumstances he had mentioned, the question of cost hardly came in, but that the engine was capable of doing its work he could certify, as he had seen it draw three heavily laden coal carts, containing about two tons each, up a steep hill with an incline of about one in eight, the carmen not troubling to get down. The engine was a traction engine of the ordinary type, built by Tasker of Andover. It had a winding-drum, so that if any difficulty occurred on a steep hill, they could stop and wind the vehicle up by means of a wire rope.

There were, he felt, difficulties looming in the future with regard to the slippery roads in the winter. The broad wheels of the "Little Giant" were provided with studs or cogs, which were to be fastened through holes purposely made in the wheels. He believed that the use of such things was not allowed; if that were so, there would be considerable difficulty in getting up the steep inclines in the winter. If the cogs were used what would be the use of the break blocks which were at present used in the wheels? There seemed to be no way of putting anything in the nature of a friction block except on one side, which would make the engine very erratic in its movements, and might easily be the cause of serious accidents. He would like to have the author's advice on the matter.

Mr. H. GLYNN WARNE said that some time ago he inquired into the cost of carrying road material by means of steam, and though his figures were lower than the figures given by the author they were all relatively the same.

He found that he could draw the road material more cheaply by motors but for the two difficulties mentioned in the paper. He could not get any motor which would be safe on a gravel-pit. In the district in which he lived it would be a great advantage if a motor could be arranged for carrying road material. It was found that carrying, by means of horse and cart, distances of from 6 to 10 or 11 miles was very expensive; but unfortunately the roads were not strong enough to bear motor cars, and the cars could not go safely into the gravel-pits. Heavy traction engines could of course go with safety where motors could not go; but the carriage of 400 or 500 tons of material by such means would damage the roads so badly that 500 or 600 tons of material would be required to repair them. He had to fall back upon horse traction. It was a pity that motors had not arrived at such a stage of perfection that they could be used for the service which he had mentioned.

The author had told them that it was a disgrace to local authorities that the roads were not all sufficiently strong to carry the motor traffic. He (Mr. Warne) was afraid that the author had not brought the same powers of judgment to bear upon that statement that he had brought to bear upon the other statements in his paper. He was quite sure that the author, if he thought the matter out carefully, would be prepared to modify that remark considerably. It must be remembered that the roads of the country were made for traffic of a different kind, and at a time when neither motor traffic nor traction engines had been dreamed of, and they had answered admirably up to the present time for the traffic for which they were originally intended; and if motor traffic was as limited as had been stated, it seemed hardly necessary to spend money in making the roads suitable for traffic of that description. Nearly all the money needed for the maintenance of the roads came from agriculturists, and any person who knew the difficulties with which agriculturists had to contend would realise that they did not view with any degree of favour the raising of money for making up country roads, sometimes remote from their own farms, for traffic which did not benefit them.

In his own district he had about 260 miles of road, 200 of which had a fair amount of traffic, and might be called upon to bear motor traffic; but at least half of the 200 miles was unfit to bear it, and would give way under heavy weights, though the surface was smooth and the roads were to all appearance in good condition. He agreed that it was desirable to make the roads hard enough to bear anything but there were financial considerations which stood in the way.

Mr. H. Conradi said that it was greatly to be regretted that the author had not added to his valuable paper some illustrations of the principal types of steam lorries. Bayley's manufacturing firm had stated that they manufactured steam-motor vans capable of taking regularly a load of 4 tons over 50 miles per day, during a regular daily service of 312 working days per annum which constituted 62,400 net ton miles per annum. The total cost was 208*l.* 18*s.* 9*d.*, or 8*d.* per net ton mile, which divided as follows :—

	£	s.	d.
Fuel—6·15 lb. per vehicle mile × 50 miles × 312 days, at 10s. per ton	21	8	4
28 lb. coke per day for raising steam × 312 days, at 10s. per ton	1	19	0
Wood for lighting fire		15	0
Water—4·9 gallon per vehicle mile × 50 miles × 312 days, at 1s. per 1000 gallons	3	16	5
Wages—Driver, 35s. per week	91	0	0
Lad, 10s. per week (to assist driver)	26	0	0
Repairs—Material and labour	52	0	0
Lubricating oil and waste	12	0	0
Total	£208	18	9

The author recommended that all roads in the United Kingdom should be made strong and hard enough to carry such heavy traffic. In answer to that, it might be remembered that the great cost of repairing and maintaining roads (not to speak of their construction) amounted, according as their position was in the country or near a town, on the average from 30*l.* to 75*l.* and even to 90*l.*, per mile at the usual average width. If wood pavement was used—as it was done at present for the road from Brondesbury Station, Kilburn, outwards to Edgware—where tramways were constructed, the cost of roadway of 40 feet in width amounted per mile to 9885*l.* by using creosoted deal at 8*s.* per square yard, which was intended to last for seven years, one mile representing in round figures 23,461 square yards. If Australian wood were used, such as Jarrah, at 11*s.* per square yard, the total cost per mile of roadway, 40 feet wide, would have been 12,904*l.*—the road intended to last for twelve years. To avoid such great cost of road maintenance, would it not be better that motor traffic for goods transport should make use of the existing tramways, and work conjointly with the tram service, instead of trying to work in opposition? Both services working together would benefit trade and industry much more than being antagonistic. To bring the goods to the door, arrangements could be made for the transfer of the goods to motor lorries, with ordinary wheels, running the short distances from the tramway terminus to the place where the goods were required; exactly as in the case of light railways or narrow gauge lines joining ordinary full gauge railway lines of 4 feet 8½ inches. The cost of transfer varied from 1*d.* to 2*d.* per ton. That provision would be much less costly than either the construction or the strengthening, and the repairs and maintenance, of the roads. Not to hamper the ordinary passenger traffic, the goods could be carried on the rails at the same speed as the passenger traffic, say from about 10 or 12 to 15 miles per hour, which would be only a question of engine power. If preferred the goods service could be carried out at night. There were railway companies here and abroad who were preparing railway motor-car service. A similar service of steam-cars, that is engine and car combined, had been already carried out, by the General Omnibus Company of Paris, for passenger traffic at the Paris Exhibition of 1889. It seemed, therefore, that there was no difficulty in working motor-car goods traffic on tramways.

He should like to know whether the motor vans which carried 6 tons on the van and 4 tons on the trailer were kept within the 2-ton tare limit. That was an engineering question, because when they had that information they would be able to judge how much more they had to play with when they had it increased to 4, 5, or 6 tons.

Mr. R. J. Thomas said that he wished to point out a few things from the road-maker's point of view which were worthy of consideration. On the 1st of January next the driver of every motor car or light locomotive would have to be licensed, but the licence did not carry with it a certificate of efficiency. The extraordinary anomaly was that the driver of a heavy traction engine would not need to have a licence at all. The driver of a light motor wagon brought before a magistrate might have his licence revoked and yet the next day drive a 14-ton traction engine. That would be the law.

One excellent feature of the new Act was that Crown servants would be brought into line with ordinary motor-car drivers. The author made repeated reference to the Middlesex County Council, which he, Mr. Thomas, did not like. He thought that the feelings of a county council were very much governed by the class of traffic which they had to deal with, and the way that such traffic was worked.

As to the licensing question, he had occasion to mention it before the Parliamentary Committee which sat prior to the 1896 Act being passed, and he urged that owners of traction engines should agree to a licensing clause for drivers. The owner, although an admirable person, might send out in charge of a 14-ton traction engine an ignorant man who would not make way for anybody, and would not be controlled by any licence. It was men of that sort who caused much of the ill feeling which existed against traction engines. If the drivers were licensed, and brought into line with the drivers of light locomotives and motor-cars, public feeling would not be so bitter towards traction engines. Those interested in the subject ought to get the Act amended in that respect.

With regard to the depreciation of light motor wagons, he had worked out the proportions put forward by Mr. Mackenzie, and they appeared to him to be excessive, a 500*l*. engine becoming worth but 30*l*. in ten years.

With reference to the table of working cost, he noticed that 5*s*. a day was put down for supervision, in addition to the driving charges, and 5*s.* a day for fuel. He did not find that the engines which he used consumed anything like such a quantity of fuel. A 2-ton engine surely did not consume 5*s.*-worth of fuel a day.

With reference to horse haulage, the cost in his county was very much lower than that stated in the table. He had about 20,000 tons of granite carted every year from the railway stations, and the maximum price he paid was 1*s.* per ton for the first mile, and 6*d.* a ton for every other mile. In some cases he paid as little as 9*d.* for the first mile, and 5*d.* for the second mile. It would be seen from those prices that motor wagons would have to work very cheaply to shut out horse traction.

Sometimes a man in charge of a road locomotive went into a strange district, and, depending upon a map knowledge of the roads rather than local, he would get into unsuitable roads. He had seen traction engines in Buckinghamshire on roads where they had no reason whatever to be. That arose simply from lack of enquiry. In such cases they used parish roads which were never meant for traction engines, although they were good enough for the local traffic. The subject ought to be considered in a broad light, because, after all, the greatest good of the greatest number was what should be aimed at.

Mr. Charles Mason said that he had been most interested in the paper. The author had, he thought, been somewhat pessimistic. He was sorry that they had not had any manufacturers of motors joining in the discussion to give their views as to the future of that rapidly increasing system of locomotion.

He was one of the "horse-worshipping" public, but, like Mr. Thomas, he thought they must do what was best for the good of the public at large and pocket their own feelings. He should like to have a few particulars of comparison between haulage by motor car and haulage by railway, as he thought motor haulage throughout the country should compete more with the railways than with horse traction, on account of the tariff. He had experienced difficulty lately with railway companies in forwarding goods, and if a really good system of motor haulage could be established throughout the land, great benefit would be conferred on the country at large. He had known half a ton of goods to be sent twenty miles by rail and lost for three weeks on the way. Some years ago, in a discussion before the Society, he prophesied that the time would come when they would see no horses at all in London. He still held that opinion with regard to light traffic.

The discussion would, no doubt, have been made more interesting if they had had the views of the principal manufacturers of motors for heavy traffic. The business of the country had to be carried on, and he thought that a great thing in favour of expediting such business would be the extension of motor-car traffic throughout the country, without interfering with the rights of non-users of motor cars.

He was an old public surveyor, and did not altogether agree with what previous speakers had said about the condition of the roads. He had seen heavy cartage over the same roads in the country for days together, and they had not been damaged to the extent described by a previous speaker.

Mr. Douglas Mackenzie said, in answer to Mr. Griffith's enquiry as to the cost of horse traction per ton-mile, that he believed that in London generally it might be taken at 8*d.* Since he had been in the hall he had been told that that figure was quite fair for London. The cost of hiring a pair of horses and a man with or without a van might be taken at 18*s.* a day. The work which they would do depended very much on the nature of the trade which they were serving: 18*s.* might be taken as the basis of calculation.

As to the question of stocking spare parts, he quite agreed with Mr. Griffith that it did not pay to stock them. The parts which broke down were the parts that were wrong, being either too weak or badly designed. The only thing to be done when parts broke down was to let an experienced engineer find out the reason, and design something which would not break down in the future. If a broken part was replaced by a part exactly similar, the new part would break down in the same manner as the old part.

The cost of working per ton-mile had been given by Mr. Griffith at from 2¾*d.* to 3*s.* That showed the difficulty of getting figures. It was only by averaging results that one could get any tabulated statement.

He had never yet come across an accumulator car used for goods traffic, and he did not think that there was one on the market. As a commercial engineer who used motor wagons for the purpose of making money, he could not afford to experiment with wagons before they had been put on the market. If anyone would produce an accumulator wagon that would take 10 tons, he was prepared to try it, but he thought that the accumulator itself for such a wagon would weigh 25 tons. He was afraid that the weight of the accumulators and their rapid depreciation would make it quite impossible to use them for motor wagons at all. He pointed out that the tare weight of a wagon did not include the weight of the accumulator, so there was no reason why makers should not put a wagon on the market which would weigh 3 tons and have an accumulator weighing 25 tons; but in that case where would the roads be?

He was pleased to hear Mr. Maurice Wilson's account of the young traction engine at Sydenham. Some of his (Mr. Mackenzie's) motor wagons had a difficulty in climbing the hills mentioned. Perhaps he might apply to the young traction engine for help.

As to the question of putting studs in the wheels in the winter, the President had said that the road surveyor would not allow them to be used. But such studs were largely used in traction-engine work in the country.

With regard to the making up of the roads, it was not every road that was wanted for motor-wagon traffic. There were occupation roads and side roads which they did not want to use at all. But, on the other hand, if the motor wagon or the traction engine was to be of use to the farmer, every road that the farm carts were likely to use must be made up. He knew that that was a very tall order, but it could be done. In the Rural District of Chipping Norton, when the present surveyor went there, every road was made of soft limestone such as was obtained from the Cotswold hills. That stone would almost break up under a bicycle. The surveyor got the permission of his council to try Leicestershire granite. He obtained a consignment, and put it on the main roads first, and on the district roads afterwards. He divided the roads in his charge into twelve parts, and did one of the twelve parts every year. The period of twelve years was nearing completion, and the roads were now magnificent. When the twelve years had expired there would not be a foot of road in the Chipping Norton district which would not carry heavy wagons. The part of the district on the Thames side of the Cotswolds was almost a desert, and he thought that if such a change could be made there, there was not any district in which it could not be carried out.

Mr. Conradi asked the tare weight of the lorry that would carry 6 tons and pull a trailer carrying 4 tons. That would depend upon the interpretation which was put on the word "tare," as used in the Act. If they had the makers present at that meeting, they would tell the members that the Act allowed them to weigh a wagon without coal and water and without any accumulator; and they argued that a boiler was an accumulator within the meaning of the Act. Whether that view would be held in a court of law he could not say. If he wanted to weigh one of his wagons he should empty the bunker and take the body and the boiler off, and then he thought that he could get the wagon down to 3 tons tare.

He quite agreed with Mr. Thomas that traction-engine drivers should be licensed. Motor wagons were quite harmless compared with traction engines, and yet there was practically no way in which magistrates could deal with the drivers of traction engines. Traction engines at times were driven very carelessly, and did a great deal of damage. Only two days ago the surveyor of a rural district near London drew his attention to a serious nuisance caused by a traction engine in the district. The engine was drawing bricks up a very steep hill, and the wheels being unable to bite, notwithstanding the cross-bars, the driver threw bricks under the wheels. The bricks were partially ground up, and the road was left strewn with broken pieces.

Reference had been made by Mr. Mason to motors competing with the railways. The experiment had been tried in Lancashire. A firm had been started specially for the purpose of competing with the railway companies, by means of motor wagons between the principal towns in Lancashire, but it had been found impossible to make the motors pay, although in Lancashire there were many large towns within comparatively short distances of one another. Mr. Mason had also spoken of the difficulty of getting a half-ton consignment to its destination by railway. The cheapest way to deal with a half-ton consignment was to take it by horse traction. Several firms in London delivered by means of horses for distances of thirty miles, on account of the difficulties and the delays which occurred in connection with the railway, and the cost of unloading the railway trucks at the station, and carting the goods to their destination. One of his motors would leave at the end of the present week with a load on a journey of 110 miles. The cost of getting such a load for a distance of a mile or two from the railway station to the point of delivery was so great that it was cheaper to send it by motor all the way rather than to send it by rail and cart it from the station. Of course, cases of that kind were exceptional, and they would only occur when loads of not less than 5 or 6 tons could be sent.

With regard to the future, he had explained in his paper that the prices which he had given were the prices of to-day. He ought to have added that they were the prices in London. The prices would be found to be cheaper in other parts of the country both for horses and for motor cars. Motors were being improved not merely every year but every day, and they were becoming more economical, more efficient, and better engined. The boilers which were obtained now were really good engineering tools, and a similar remark applied to every part of the motor. Until some experience had been obtained engineers did not know what difficulties they had to meet, but now that the difficulties were known, the engines were designed in a way that would meet them. He had recently drafted out a design for a new motor wagon; it would be most hideous in appearance, but he believed that it would do its work well, and that it would even be able to pull out of a gravel-pit. He hoped that next year somebody would place before the Society the condition of affairs which ruled then. It would be found to be very different from the condition which existed at the present time.

November 2, 1903.

J. PATTEN BARBER, PRESIDENT, IN THE CHAIR.

THE BACTERIAL PURIFICATION OF SEWAGE.

BY GEORGE THUDICHUM.

SINCE first the author had the honour of appearing before this Society with a paper upon the purification of sewage by the aid of micro-organisms, a vast amount of knowledge has been added to that which was then available regarding the various processes. Extensive experiments, lasting over months and years, have been undertaken by great towns in this country, and the results, generally speaking, have been most gratifying. The acceptance of the principle that, in the large majority of cases, sewage can be purified by biological means alone, properly conditioned and regulated, is now almost universal; and the seal has been placed to this acceptance by the dictum of the Royal Commission on Methods of Sewage Treatment, in their interim report of 1901, that "it is practicable to produce, by artificial processes alone, either from sewage, or from certain mixtures of sewage and trade refuse, such, for example, as are met with at Leeds and Manchester, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance." That by "artificial processes" the Commissioners mean biological methods is clear from the list given of the processes examined, in which, out of ten mentioned, chemical treatment occurs in two only, as a preliminary to final purification by bacteria beds. This being so, there is clearly no longer any need to fight the battle of the microbe. The biological principle has been fully and finally adopted. and what remains for discussion is the best method for its application.

One point, and that a most important one, regarding which there has been in the past a wide divergence of opinion on the part of two schools, is the advantage or otherwise of an anaerobic treatment as a preliminary to the aerobic or finishing treatment. On the one side it was stated that putrefactive processes were unnecessary and obnoxious and that the whole of the operations could be successfully carried out by resorting to the aid of aerobic organisms alone. On the other, it was claimed that such processes were both natural and necessary, and that a coarse-grain bacteria bed did in fact work anaerobically, despite the conditions. Whether these claims are justified in their entirety may still be open to doubt; but regarding the great desirability (as distinguished from necessity) of a preliminary anaerobic treatment, there is now a body of evidence which has convinced the great majority of those studying the subject, including the advisers of the Local Government Board. In fact, the author believes that there are now but very few amongst the well-known experts on sewage treatment who still view the so-called "septic" process with disfavour. The reasons for this general acceptance of the anaerobic method are not far to seek. In the first place, the solutionising of the solid matter, or the preparation of the sewage for treatment on a fine-grain bacteria bed, is effected without any appreciable loss of head, a fact which is of the utmost value when the available fall is small. The tank also averages the sewage, causing the effluent discharged on to the aerobic beds to be far more constant in its nature; and it is also employed to regulate the rate of flow to a certain extent, and thus ensure a proper periodic working of the filters. Another advantage is that loss of capacity in the tank, due to collection of solid matters, does not, unless in extreme cases, affect the quantity of sewage which can be dealt with by it daily; whereas the loss of capacity in a bacteria bed does diminish the volume of sewage which it can pass; and, in the event of cleansing becoming necessary, the work of removing the deposit from a septic tank is very light, compared with that which would be required to wash the bed material of a bacteria bed of equal working capacity.

These points, it will be observed, are not questions of doctrine, but of convenience and economy in practical working. It is probable that such considerations alone would influence the decision of local authorities and their advisers, when debating the various claims of different processes submitted for their adoption; but a meeting of this kind should go further, and endeavour, by comparing the different views and observations of those most conversant with the subject, to arrive at some definite judgment as to which method follows Nature more closely. The author has on many occasions expressed the opinion that sewage can be purified by means purely aerobic, and he is still of that opinion. The illustration which he gave during the discussion on a paper by Dr. Rideal, read before the Society of Arts a few years ago, appears to offer very strong evidence in support of this view. This was an experiment, made long ago by Dr. Dupré, in which he showed that a small quantity of sewage, mixed with a proportionately large bulk of fully aërated water, was completely oxidised without the whole of the dissolved oxygen being consumed; and under these conditions it is difficult to assume the existence of any anaerobic action. This experiment is strictly parallel with the conditions obtaining when the sewage of a small collection of people flows directly into a considerable river, and mixes itself with the large bulk of pure and aërated water, constantly renewed. Neglecting, for the time, the question of pathogenic organisms, the sewage of such town might continue to be discharged indefinitely, without any fear of injury to its neighbour next below it, provided the distance between the two were sufficiently great to admit of the time interval required for full oxidation, and for the river water to be once more fully aërated, without any demands being made upon its dissolved oxygen by sewage matters.

But let the question be asked: "Is even this a natural condition of things? Does not the very collection of waste matters, and their discharge in bulk into a stream, constitute an artificial state?" All animals, except civilised man, deposit their dejecta where and when the necessity arises, and, certainly in the case of solid matters, the first step towards purification is putrefaction. This is also true of all collections of dead organic matter, whether it be the body of an animal or a heap of dead leaves. To such an extent has this been recognised, although without knowledge of the meaning of the observation, that farmers frequently, as the author has on many occasions heard personally, judge of the value of a manure heap by the amount and nastiness of the odour emitted therefrom. From such considerations it would appear that, in following the septic method of preliminary treatment, we are assisting Nature; in the attempt to perform the same operations aerobically, we are coercing her. And though such coercion may be successfully employed in many matters, it rarely follows that the results are really comparable with those obtained under natural conditions. The author's opinion therefore, arrived at after years of careful study of the subject, is that, although not an actual necessity, the employment of the anaerobic method, as a preliminary to final oxidation, is eminently desirable, both for practical reasons and as being more in accord with the teachings of Nature.

The necessity for closely covering a septic tank has been frequently discussed. The experts, appointed by the Manchester Corporation to consider the best means of treating the sewage of that town, decided that quite as good results could be obtained with an open as with a closed tank; and many later observations by others have confirmed this view. But here again the question of desirability *versus* actual necessity arises. A tank, fully exposed to the atmosphere, nevertheless performs its anaerobic function thoroughly; and the expense of close roofing being saved, the process must compare favourably, from an economic point of view, with the coarse-grain contact bed, since the total cubic contents of tank and bed are equal, but the latter has to be filled with some contact material. This, of course, is a very strong recommendation for using the open tank. But, and especially in the neighbourhood of dwelling houses, there is always the possibility of nuisance arising from the uncovered tank, especially if disturbed accidentally or by high winds. It is well known to most people that the effluent from a septic tank, carefully removed without disturbance, has but a very slight odour—indeed, in a tank itself, where everything is practically at rest, there is no smell which can be described as objectionable. But if the sample be shaken, or the contents of the tank be stirred up, the observer's olfactory sense is immediately assailed in a most unpleasant manner.

Again, since the scum which collects on the surface of the water in the tank is undoubtedly the seat of very great bacterial activity, its disturbance and rupture should clearly be avoided if possible. For these two reasons it would appear that some amount of roof protection should be given. There is yet a further point to be considered in deciding this question, and that is the commercial one of collecting the gases formed during the action. At Exeter the gases are so collected and utilised; and this should be possible, anyhow in the case of all large installations. There is no need to be alarmed by the fear of explosions, such as have unfortunately occurred in a few instances; on the contrary, they are really evidence of the existence of available power, for the gas which can form an explosive mixture, sufficient to blow off the roof of a concrete tank, can certainly work a gas engine, or can be used, with the aid of an incandescent mantle, for the production of light. If, however, such use is to be made of it, the light roof, which would serve as a protection against weather, disturbance and possible nuisance, would be of no avail; but resort must be had to the gas-tight covering originally designed. In all large plants, then, the author considers that the covered tank possesses distinct advantages over the uncovered, quite independently of the question as to whether the efficient working of the anaerobic organisms is in any way affected.

The remaining question, which has of late given rise to much controversy, is the method of applying the effluent from septic tank or first contact bed to the aerobic filters. The author has no intention of discussing the relative merits of the many patent forms of apparatus designed for this purpose, but merely to consider the general point : Is it better to employ the contact system —that is, filling, allowing to stand full for some given time, and emptying, followed by a rest period of some hours' duration ; or to deliver the effluent in frequent but small charges, the bed never being either filled or completely drained ? As regards this question, there appears very much to be said on both sides. Excellent results have been obtained by either method. Judging from the numerous forms of gear recently introduced, it would appear that the general tendency is rather towards the intermittently continuous or sprinkling style. It is a matter that still requires elucidation, and on which much work remains to be done.

A question which the author thinks might well be considered at a meeting such as this, is that of sewage discharged into estuaries or into the open sea, and especially in connection with the possible pollution of fisheries. This question has been very prominent of late years, owing to various outbreaks of typhoid fever, which have been traced to the consumption of oysters, cockles, or mussels, from collecting areas which are more or less exposed to sewage contamination. There can be no doubt that the discharge of crude sewage, either into the open sea in the immediate neighbourhood of watering places, or into sea or estuary close to oyster beds or cockle grounds, is improper and dangerous, and should not be permitted. But, on the other hand, are not the requirements in this respect more than is actually necessary ? The author has in mind the case of a town, situated upon a tidal river, in which, some little distance below the town, oysters are cultivated. The crude sewage of the town has been running into this river for a long time ; the bulk of tidal water, as compared with the sewage, is very great ; and no injury has as yet been suffered by persons eating the oysters, which, moreover, are principally used for transplanting. It is proposed to treat the sewage by septic tank and aerobic filters ; but apparently the town has been unable to satisfy the superior authorities that the method suggested will produce absolute safety ; and permission to proceed with the works has, anyhow up to a short time ago, not yet been granted, although the inquiry took place some twelve months since.

In the second report of the Royal Commission on Sewage Treatment, it is stated by one of the Commissioners' expert advisers, that the septic tank is clearly hostile to the development of *Bacillus typhosus*, and that the general reduction of all organisms in passage through tank and filter is practically the same as that of the organic matters, or about 75 per cent. To absolutely remove all possibility of some pathogenic germs escaping with the effluent, it would be necessary to have an elaborate system of filtration, such as that which is employed for drinking water, the cost of which would be enormous. The author would ask, is it really necessary to insist upon such a high degree of purification? Is not the microbe hobby being ridden a little too hard, and that not in sewage questions only? If perfection cannot be attained, except at a cost which is utterly prohibitive, is that any reason why the adoption should be delayed of what is admittedly a very great step in the right direction? absolute safety we can hardly hope to arrive at; relative safety, on the other hand, is easy of attainment. The author considers that no town should be prevented from taking steps towards improvement, provided such steps are in accord with the latest knowledge as to methods, and do not entail any serious waste of capital in the event of its being found possible, in the future, to advance still further.

Of the impropriety of discharging crude sewage in the immediate vicinity of watering places there can be no doubt. The author once stood, with several others, shivering on the deck of a steamer anchored a short distance off the pier of a well-known seaside resort, waiting to enjoy a swim on a fine summer morning, but deterred from entering the water by a continuous stream of solid fæcal matter, which flowed steadily past the ship for a long time on the young flood. Whether the conditions which rendered this possible have been altered now, the author does not know. If levels and available means do not in such a case admit of full treatment, the adoption of a septic tank would anyhow prevent such a collection, and would send the sewage into the sea in a condition in which it would mix with the sea-water readily, as had happened with the liquid portion in the case referred to. Where the cost is not too great, aerobic filters should be added in the case of all populous places.

If apology were needed for adding yet another to the already very lengthy list of essays on the subject of sewage treatment, it would be found in the fact that such papers almost invariably produce a most animated discussion, showing that, however the general knowledge of the question may have advanced, there still exist many and most divergent views concerning it. That this should be so, in view of the great progress made during the last twenty years, is somewhat surprising, and would appear to arise from the fact that the majority of those interested are unable to look at the question as a progressive one, the knowledge concerning which is built up step by step, as each observer notes some new point; but are rather inclined to the view that when their particular point has been displayed, finality has been reached. This is a great pity, since it leads to a discussion of individual hobbies, instead of a comparison of carefully observed data.

As showing how a process is finally developed from the work of a number of experimentalists in different fields, a study of the evolution of the so-called "Sutton" system—viz. that which deals with crude sewage in a coarse grain bacteria bed—may be followed with advantage.

Here we have a perfect sequence of advances, from laboratory experiment and speculation, founded on observed results, up to the completed machine. This sequence, in rough chronological order, is as follows:—

Schloesing and Muntz.—Discovery of the nitrifying organism.

Warrington.—Nitrification experiments.

Dupré.—Suggested that it might be a good thing to cultivate the low organisms on a large scale, and discharge them, with the effluent, into the river.

Dibdin.—Bacteria . . . . are most potent in the destruction of all objectionable refuse. Suggested that probably the true way of purifying sewage would be to separate the sludge, and then turn into the effluent a charge of the proper organism, specially cultivated for the purpose.

Massachusetts Board of Health.—Sewage can be completely purified by the aid of micro-organisms alone.

Barking Filtration Experts.—An effluent, containing 10 parts of suspended solids per 100,000 parts, successfully dealt with, in large quantities, by microbial means only.

Waring.—Passed roughly strained sewage through a coarse-grain bed until it commenced to choke; then oxidised by blowing air through, and thus providing suitable conditions for the aerobic organisms to work.

Dibdin.—Filled a coarse-grain bed with sewage, allowed it to stand for some time, ran off the clarified effluent, and allowed the air thus drawn into the interstices of the filter to take the place of the forced aëration.

It is not pretended that this list is in any sense a complete one, as there were many other workers in the same field during the years named; but it illustrates admirably the manner in which the several efforts of a number of individuals produce the final, workable method.

The author does not claim to have advanced anything new in this paper; his intention has rather been to give a brief résumé of the present position of the question, in the hope that, during the discussion which he trusts to arouse, the results of the latest practice and experience may be placed before the Members of this Society.

DISCUSSION.

The PRESIDENT said that he had much pleasure in proposing that the thanks of the Society be given to Mr. Thudichum for his kindness in reading the paper. The Society of Engineers was always glad to welcome communications with respect to sewage purification or water supply from chemists, because engineers recognised that the question was one requiring the advice of the chemist as well as the skill of the engineer in constructive works; and he was pleased to note that throughout the country engineers and chemists had worked together in great harmony, in the brotherly way which had always characterised the work of scientific men. The public had been much benefited by the co-operation of engineers and chemists. The work which must be done before the last word was said with regard to sewage purification could never be done by the engineer alone, or by the chemist alone. It was significant that chemists could come to a meeting of engineers and contribute freely their quota of knowledge and experience to the solution of that question. He was sure that the meeting was very much obliged to Mr. Thudichum for the light that he had thrown upon the subject. Their thanks, moreover, were doubly due, inasmuch as Mr. Thudichum had written the paper at extremely short notice, the Council having been disappointed of another paper which had been promised for that evening.

The Vote of Thanks was carried by acclamation.

The SECRETARY then read the following communication from Dr. J. C. Thrush, D.Sc., M.D.

During the last few years I have had to give great attention to the subject of sewage purification by bacterial processes, and in the county for which I act as medical officer of health I supervise a number of sewage works in which these processes are employed, and at regular intervals make chemical analyses of the effluents. Besides this, I am making analyses of effluents from various experimental works in which different systems are employed. Another part of the subject, that of the effect of sewage upon shell-fish has also, recently, been the subject of investigation by me, since the Essex coast is markedly affected by the sewage of London and other towns, and shell-fish from the coast (especially cockles) are continuously spreading typhoid fever.

Mr. Thudichum is so guarded in his statements that he gives little cause for criticism, and I will therefore only refer to such portions which do not entirely agree with actual results observed by me.

Mr. Thudichum has nothing to say about the "contact" system of filling coke beds, but he asserts that the "intermittently continuous or sprinkling style" requires further elucidation. This may be correct, but I think it may now be safely asserted, and I assert it as the result of many observations, that there is no longer room for doubt that the sprinkler system produces an effluent far better, both chemically and bacteriologically, than can be produced by the "contact" system. This applies equally to raw sewage and to septicised sewage.

With reference to the use of septic tanks, I am still sceptical. From claiming the liquefaction of 80 per cent. of the suspended matter, the claim appears to have fallen to 20 per cent. My impression, based on observations at different sewage works, is that a fairly large and properly managed detritus-tank is all that is required, and gives, with suitable after-treatment of the sewage, results as good as can be obtained either by open or covered septic tanks; and that the production of gas, and slight amount of suspended matter destroyed, bears no reasonable relation to the enhanced cost. I am quite convinced that with an intermittently continuous or sprinkler method of treatment, previous passage through a septic tank is quite unnecessary. One point upon which I remained in doubt for some time, was whether the application of the settled sewage would not more speedily choke up the coke beds or more seriously affect their capacity than septicised sewage. My observations have led me to conclude that such is not the case. In fact, the coke beds appear to be much cleaner beneath the surface when settled sewage only is used.

The subject of the necessity for submitting the sewage of coast towns to some system of treatment before allowing it to be discharged into estuaries and into the sea, is a large and important one. There may be a few cases in which neither screening nor subsidence may be necessary, but in the great majority of cases some system of treatment is very desirable. Confining my attention to those localities near which shell-fish is dredged, the sewage should either be efficiently treated or the shell-fish fishing abandoned. I am afraid that "shrimps" come under the category of "fish" capable of causing typhoid fever, and shrimping on a polluted fore-shore should not be permitted. By bacterial treatment over 85 per cent. of the organisms in sewage may, I believe, be removed. Such treatment would, therefore, very materially reduce the danger of contamination; and it may possibly be shown will reduce the danger of specific contamination by the typhoid or cholera bacillus to a negligible minimum. This, however, remains to be proved.

Expensive systems of sand filtration referred to by Mr. Thudichum may not be the only ones capable of effecting adequate sterilisation. Heat is a more efficient steriliser, and it is probable that in the near future it will be found possible to sterilise sewage effluents by means of heat at a trifling cost. If this should prove to be the case, there would no longer be any necessity, in most cases, to produce an effluent of a high standard of chemical purity. The whole of the danger which arises from sewage is due to the microbes it contains, and the degree of microbial purification produced by any system should receive as much attention as the degree of chemical purification.

Mr. W. D. Scott-Moncrieff said that he somewhat sympathised with Dr. Thresh in his view that the paper was an exceedingly indefinite one, but the President had explained that Mr. Thudichum had but a very short time for its preparation. It was difficult to discover whether the conclusion arrived at, was the author's own conclusion, or whether the process apparently advocated was really believed to be the best. Dr. Thresh had referred to one or two points, as to which the author had committed himself in more or less vague statements, and he (Mr. Scott-Moncrieff) was afraid that he could do little more than follow Dr. Thresh in an attempt to arrive at what the author really meant, and to discover which horse he was riding. A few words might be said with advantage on a point raised by Mr. Thudichum, as to the possibility of sewage being purified by an exclusively aerobic process. That part of the paper showed how vague the terms were which the author employed in discussing that very important subject.

The author had expressed his opinion that sewage could be purified by a purely aerobic process, and he proved his statement by referring to an experiment made long ago by Dr. Dupré, in which a small quantity of sewage, mixed with a proportionately large bulk of fully aerated water, was completely oxidised without the whole of the dissolved oxygen being consumed. Some time ago, a statement of that sort might have been accepted as definite, but at the present time it became necessary to ask what Dr. Dupré meant when he spoke of sewage. If he referred to sewage which had taken two days to arrive at the point of discharge where the experiment was made, such sewage would have been subjected to a very considerable anaerobic and putrefactive change before the experiment was made, and the statement that the conditions were purely aerobic would not be true. Unless they reasoned on a much more scientific basis statements of this kind would be of no value whatever. The terms employed should be definite, and it should be clearly understood that experiments made to show the possibility of purifying sewage under a purely aerobic system, must not be made with samples submitted to anaerobic fermentation beforehand, as he thought exceedingly likely to have been the case in the experiment referred to by the author as conclusive evidence.

Although suggesting that it was unnecessary, Mr. Thudichum had nevertheless emphasised the advisability of a certain amount of anaerobic treatment beforehand. Here again was the same extreme indefiniteness. The question of anaerobic fermentation must ultimately be expressed in some definite terms before it could have any definite value. The author had said that no town could be prevented from taking steps towards improvement, provided that such steps were in accord with the latest knowledge as to method; but he the (speaker) did not think that the paper which had been read would give much guidance in the matter. He noticed in the chronology given in the paper that Mr. Dibdin appeared as having suggested that probably the true way of purifying sewage would be to separate the sludge. Then the Massachusetts Board of Health experiments followed; then followed the Barking filtration experiments, which were those of Mr. Dibdin. So far back in the history of the subject as 1892 he (the speaker) showed Mr. Dibdin anaerobic fermentation going on in a cultivation tank and the liquefaction that was taking place, but the facts did not influence Mr. Dibdin's views in any way. He went back to Barking, and all his experiments were conducted without the slightest hint of previous anaerobic fermentation being an advisable preliminary to aerobic purification; so much so that the chemical treatment at Barking went on as if septic treatment had no existence. He thought that a definite expression of opinion one way or the other, such as that which had been made by Dr. Thresh, should be made at meetings of a professional society with regard to contact and percolation beds. Both of them could not possibly be right.

He believed that in Staffordshire there were a larger number of old established successful bacterial systems at work than in any other county in England, and Dr. Reid, the medical officer of health of that county, had been intimately associated with every one of them; yet, at a recent meeting of the Sanitary Institute at Birmingham, Dr. Reid gave his opinion that for all practical purposes contact was dead. There was, however, no account of its death in the paper; and the question whether it was dead or whether it ought to be resuscitated ought to be threshed out at a meeting of this sort.

He had always maintained that nothing approaching perfection with regard to effluent had been obtained from any contact bed which ever existed. A high ratio between the oxidised and the unoxidised nitrogen in the effluent had never been reached in a contact bed, and never would be. Quite recently, however, a strange development had taken place. It was now suggested, by one of the ablest exponents of the system of contact, that when a fairly good effluent had been obtained it should be mixed with a worse effluent, or with other sewage, so that the average result due to the continuance of the bacterial action in the mixture might produce an effluent which was good enough for any particular place. That reopened the whole question of the efficiency of the contact system, by suggesting that the period of high oxidation should be used to compensate for the period of low oxidation in the filter bed.

What he (Mr. Scott-Moncrieff) had maintained for many years was, that if they followed nature's methods carefully and implicitly they would, as a matter of fact, obtain an exceedingly high ratio between the oxidised and the unoxidised nitrogen in the effluent, throughout the entire process. The ratio that he had obtained was as high as 98·6 per cent. It was true that purification did take place during the septic period in a contact bed, but that purification was obtained at the cost of a great loss of nitrogen in a gaseous form.

That reopened the whole question, and put the advocates of contact beds in this dilemma that while they were arguing the importance of nitrates as a means of raising the average quality of an effluent, they were at the same time employing a process which dissipated the greater part of the nitrogen in gaseous forms. The anaerobic condition in a contact bed often went on until all the available oxygen was used up, and the moment that happened the bed altogether ceased to be aerobic in any sense, and might cease to be aerobic in character, as Mr. Dibdin discovered at Barking with his acre bed, for weeks and months, yet Mr. Thudichum had given great emphasis to the advisability of adopting contact beds. Neither Mr. Thudichum nor Mr. Dibdin, nor Dr. Fowler, had the faintest idea how much outside air was actually being consumed in the system they advocated, and as long as that went on they were not on a scientific footing but were only blind men leading the deaf. What all the world did know was that the air was not sufficient when measured by the results.

Until they knew in definite terms what actually took place with regard to any particular sewage, and how much air was used, and the quantity of air necessary, for the full charge to nitrate, they must necessarily be working in the dark. He was unable to conceive how, under any circumstances, that natural zonal sequence of environment, which was essential to the success of bacterial action, could take place when the bed was filled with liquid. It was true that in the emptying of the tank a charge of air was drawn into the tank, and that that air was available while the tank was empty for the work of the nitrifying organisms. It was true that in that way they got, at a certain period, a large amount of nitrification. But although organisms could survive great ordeals in the way of food and environments, no organisms could possibly produce high nitrification throughout that exceedingly unfavourable condition provided by a contact bed.

He hoped that in trying to be more definite than Mr. Thudichum he had not been in any way discourteous in his remarks. He felt very strongly that the present subject ought to be tackled in a more vertebrate fashion, and he did not think that loose talk and vague statements, which did not deal with the scientific points involved, should be accepted without protest now that so much was known of the subject. He hoped that Dr. Thudichum would yet take up a more vertebrate position, and would be satisfied that contact was either right or wrong, and give good scientific reasons for his opinion.

Mr. ARTHUR J. MARTIN said that he was sorry not to be able to agree with Dr. Thresh and Mr. Scott-Moncrieff. His own pleasure in hearing the paper had been none the less because it was lacking in those sweeping dogmatic statements which they were accustomed to find in the papers of amateurs on sewage disposal. A man of the ripe and almost unrivalled experience of Mr. Thudichum must necessarily approach the subject from a calm and scientific standpoint. He could not conceive a man of experience, in a matter of this kind, putting forward the bald and one-sided statements which appeared to have been looked for by Dr. Thresh and Mr. Scott-Moncrieff.

It was a matter of personal gratification to him (Mr. Martin) that Mr. Thudichum should have come to the conclusion that a preliminary anaerobic treatment was desirable in dealing with sewage. As he said in his paper, this was not a matter of compliance with any preconceived doctrinal view, but they had to consider convenience and economy in practical working. That seemed to be the keynote of the paper.

He was rather surprised that at the present time Dr. Thresh should cast a doubt on the desirability of a definite anaerobic treatment. Dr. Thresh had recommended instead of a septic tank a moderately large detritus-tank. That experiment had been tried, and it seemed to have been stamped with failure. A certain amount of good could undoubtedly be done with a detritus-tank, but a tank of small capacity must before long get bunged up with solid matter. Consequently a large amount of undigested material in an active state of putrescence had to be taken out, and a nuisance arose; and in that way the septic method was brought into disrepute. If, on the other hand, the tank was large enough to effect the mineralisation of the organic matter (so far as it could be carried), they would obtain a residuum which was inoffensive, small in bulk, and capable of being dealt with without nuisance.

The septic tank laid down in Exeter in 1896 had been used continuously ever since. It was at work five years before it became necessary to remove any solid matter from it. A few weeks ago he had the pleasure of inspecting the very interesting installation at Birmingham. They were told by the engineer, Mr. Watson, that he had had septic tanks working for four years and two months without being emptied. One was drawn off on the occasion of the visit, exposing the deposit on the floor of the tank. The assistant who showed the visitors round the works called attention to the markedly inoffensive character of the deposit. That illustrated the effect of having tanks large enough to do their work.

The point around which the discussion seemed to be ranging was the question of continuous filters versus contact beds. Mr. Scott-Moncrieff told them that the effluent in a contact bed was placed under anaerobic conditions, in defiance of the fact that the effluent on being drawn off was found to contain a large amount of dissolved oxygen, the amount being far larger than could be accounted for by oxygen becoming entangled with the liquid during the process of emptying. Some persons proved to their own satisfaction that a contact bed could not effect any considerable amount of purification, but the answer to that was that it did so. That was shown not merely by analyses of single samples, but by a series of analyses made by Dr. Fowler, of Manchester, extending over a number of years. Those analyses showed as high a purification by means of contact beds as was claimed for the much vaunted system of continuous filtration.

The record for a high ratio of oxidised to unoxidised nitrogen was claimed by Mr. Scott-Moncrieff, and he thought claimed deservedly. He (Mr. Martin) thought that he was entitled to claim, on behalf of his firm, the record for the percentage of purification effected by a septic tank and a single contact. The results obtained by that means at Leeds and Manchester were comparable with those from continuous filters. He took it that no advocate of contact beds would deny that, if the conditions aimed at by continuous filters could be obtained they could get a condition as near perfection as possible; but he must say in that connection what Mr. Thudichum had said in his paper with regard to the septic tank, viz., that they must be influenced not merely by doctrinal considerations but must also have regard to economy and convenience of working. With the contact system they got an absolutely perfect distribution throughout the bed. Whatever intrinsic merit might be claimed for the continuous system, a perfect method of distribution on that system had yet to be devised. It must be borne in mind that the contact method had now stood the test of about seven years' working. When the continuous method had stood a similar test, they would be able to come to a better conclusion as to its practical merits.

Possibly the most important point in the paper was Mr. Thudichum's protest against the practice of preventing a town from making a great and much-needed improvement in the method of disposing of its sewage, because it was not prepared to go to the expense of endeavouring to accomplish that which everybody knew could not be done. With all respect to Dr. Thresh, it was absurd to talk about sterilising sewage. The process of sterilising by heat might be carried out in the laboratory, but if those who insisted on the necessity of towns sterilising their sewage by heat realised that to do any practical good it was necessary to sterilise, not merely the dry weather flow, nor six times the dry weather flow, but the whole quantity which came down the sewers in wet weather, and would work out the coal bill for one year, there would, he thought, be less heard on the subject.

He was rather surprised at the instance quoted by Mr. Thudichum of the refusal of the Local Government Board to sanction the pouring of sewage effluent into an estuary containing oysters, because that Board had not long since sanctioned the discharge of tank effluent into a channel containing cockle fisheries, and he believed that cockles were more sensitive to pollution than oysters. At the inquiry, no less an authority than Dr. Klein gave evidence to the effect that he saw no possibility of the germs of typhoid passing through a septic tank. That statement went beyond what he (Mr. Martin) had expected at that time; and he should have thought that the authority of Dr. Klein would have been good enough for even the Local Government Board.

Mr. H. C. H. Shenton said that the author had stated that the chief thing which remained to be discussed was the best method of the application of the bacterial system. He hoped that no apology was needed for discussing practical details of construction.

Any unprejudiced person who visited a number of works, would be struck with the fact that contact beds, filters, continuously aerating filters, or land, each and all produced very good effluents at different places, and it was surprising to hear anybody say that the contact bed did not really produce a good effluent. Facts proved the reverse to be the case.

As to the statement that the contact system was dead, he entirely disagreed with it, both for the reason given, and because he, having put in contact beds, had got good practical results from them. That the results were good theoretically, which was another matter, he could also show by analysis. He considered that it was wrong for anyone to infer that the contact bed system was dead.

With regard to continuously aerating filters, he thought that Colonel Ducat and Mr. Scott-Moncrieff had both pointed out that in severe weather a filter would be adversely affected. Also, in hard winters, like that of 1895, would not the sprinkler on such a filter freeze solid?

As to the open tanks, he thought that there were great objections to them. The wind was apt to blow upon the surface, break the scum, and cause a smell, and roll the scum up to one end, and that end would become full of solid matter. If the outlet was at that end, solid lumps of scum would be discharged. It was far better to have a light roof, say of corrugated iron.

He would like to ask the author what he considered to be the best depth for a septic tank. Seven feet was very often assumed to be the best, because the Exeter tank was that depth, but was it not a fact that, if the tank were made deeper, it would take longer to sludge up? He believed that one septic tank, to which public attention had been drawn, had been condemned because it discharged solid matter. That tank was stated to be only 4 feet 6 inches deep at the outlet end. The scum was often 2 or 3 feet thick on an open tank at times, while sludge might accumulate to that depth also without harm. That solid matter would be liquefied, and the tank recover its liquid capacity. Obviously, a tank 4 feet 6 inches deep would be too shallow to deal with such a case.

The author had referred to explosions in tanks, and said that there was no fear of them. But two or three men had been killed by explosions. He should think that, where closed tanks were used, they ought to be carefully ventilated to prevent such explosions.

Mr. Scott-Moncrieff had given to the Royal Commission the result of some very interesting experiments with regard to the length of time sewage should stay in a septic tank. It appeared as if sewage could be kept there too long. If it were kept in the tank for a certain time, the liquid came out in a better state for after-treatment in filters or contact beds than it went in. If, however, it remained too long in the tank, it came out in a worse condition. Now it would be exceedingly interesting to know what was the exact point at which the sewage was in best condition for after-treatment; in fact, how long should it stay in the septic tank before being discharged? He thought that the experiment in question was not quite complete when Mr. Scott-Moncrieff gave his evidence, and it would be very interesting to hear more. He had gathered from the evidence that it was possible to keep the sewage in the tank too long to be dealt with properly, either by continuous filters or by other bacterial treatment.

He would ask the author whether the presence of the black material in contact beds which was called humus could not be got rid of by practical means? If it washed out of the tank, could it not easily be intercepted by troughs or pits? If it washed through the first bed, could it not be intercepted in channels on the second bed, and so on? That was the material which clogged the beds. Grit was generally intercepted, and organic matter would liquefy, but humus remained, and if a bed clogged it would be with that stuff. It would be worth while to take some steps with regard to it.

Mr. Scott-Moncrieff referring to the remarks of Mr. Shenton, said that he (the speaker) had carried putrefactive fermentation to a point at which it was apparently impossible to get nitrification afterwards from filters which gave very high nitrification when the sewage had been subjected to a twenty-four hours' septic change. He had used inverted vessels in a septic tank which occluded the gas, so that a very highly anaerobic process supervened. As to the question whether it was possible to keep the sewage in the tank too long, the chances were that if it was kept in long enough it would purify by itself, say in the course of two years or perhaps less. The standard period of anaerobic fermentation was one of the many points which were altogether unsettled, and about which the loosest possible talk was going on. The proper period of anaerobic fermentation in a particular tank, was relative to the time during which the anaerobic change had been going on in the sewer before the sewage reached the tank. In the case of London, it would sometimes be sixty hours before it reached the outfall, and presumably it would have undergone a much greater putrefactive change than sewage arriving fresh at the works. There were not any scientific terms available to meet the circumstances.

Dr. RIDEAL said that the author at the end of his paper disclaimed having advanced anything new on the sewage problem; but he thought that they might be congratulated in having, for the first time, Mr. Thudichum's own views upon the sewage problem. Hitherto, Mr. Thudichum's views had been identified with those of his late partner, but now that he was free from the partnership, it was interesting to see the amount of variation in those views. He thought that the most important change that had taken place was the statement made by Mr. Thudichum which underlay practically the first half of his paper—that an anaerobic preliminary was desirable, and that a septic tank was desirable. But Mr. Thudichum had not gone to the extent that he (Dr. Rideal) did some years ago, and say that they, or their equivalent, were necessary. In saying that anaerobic treatment was desirable as a preliminary, Mr. Thudichum had thrown aside entirely the views of his late partner, that it was possible to deal with crude sewage by the contact bed. He hoped that they would ultimately get Mr. Thudichum exchanging the word "desirable" for the word "essential" with regard to a septic tank.

As the opinion that an anaerobic preliminary was desirable came from a chemist, he (Dr. Rideal) would like to say as a chemist that the reason that he had used the adjective "essential" was, that he firmly believed that it was impossible to deal with crude sewage thoroughly by air, notwithstanding any argument of Mr. Dibdin or the half-hearted arguments of Mr. Thudichum in the present paper.

He had brought the new edition of Mr. Dibdin's book to the meeting, and had looked through the part dealing with that particular point, and he really could not find any sound argument in favour of the possibility of crude sewage undergoing aerobic purification. In the present paper Mr. Thudichum said, "The author has on many occasions expressed the opinion that sewage can be purified by means purely aerobic, and he is still of that opinion. The illustration which he gave during the discussion on a paper by Dr. Rideal, read before the Society of Arts a few years ago, appears to offer very strong evidence in support of this view:" that is, the view that the aerobic process was capable of dealing with sewage. But when they came to examine what the evidence was, it was not evidence of Mr. Thudichum at all. It was an experiment made long ago by Dr. Dupré, in which he showed "That a small quantity of sewage (*sic*) mixed with a proportionately large bulk of fully aerated water was completely oxidised without the whole of the dissolved oxygen being consumed."

That was not Dr. Dupré's experiment and it was erroneously quoted by Dr. Thudichum in the paper. Dr. Dupré's experiment was given in Mr. Dibdin's third edition, and the experiment consisted in taking the dissolved matters in sewage, mixing them with a large quantity of water, and then finding that there was dissolved oxygen if the mixture remained a certain length of time. He did not take the solid fæces, nor the fat, nor the cellulose, nor any of the solid matters of sewage, so that the experiment was not made with a crude sewage as stated by Mr. Thudichum in the paper. It was made with sewage from which all the solid matters had been removed. That was the very condition which the septic tank brought about. It removed the solid matters before the sewage underwent aerobic change. If that was the only evidence which Mr. Thudichum could bring forward in favour of the old-fashioned Dibdin contact bed, he thought that now Mr. Thudichum was separated from his partner he must change the word "desirable" into "essential." Dr. Dupré was a man whom he (Dr. Rideal) respected very much, and he was a very careful worker; and Dr. Dupré's experiment was perfectly accurate. His Local Government Board report was very useful and pioneer information, showing that it was completely possible to mix sewage, free from suspended matter, with a large volume of water saturated with oxygen without any putrefactive phenomenon. But that was quite a different question from the one which was under discussion.

There was another argument relied on by Mr. Dibdin. He said that it was well known that urea broke up under the influence of organisms, forming first of all ammonia and water, and that subsequently, by means of fresh organisms, all the ammonia was converted into nitrites, and then into nitrates; so that three sets of organisms were necessary to convert urea into the final nitrate. One point he wished to impress upon Mr. Thudichum was that the first change, the conversion of urea into ammonia or ammonium carbonate was a change which was called hydrolytic. It was a change that consisted in the re-arrangement of the molecules of water without any oxygen whatever. Urea broke up, as chemists perfectly well knew, without any oxygen, into ammonia and carbonic acid. It was only when the ammonia had been formed by the preliminary breaking up without any oxygen that it could be oxidised in a contact bed or a continuous filter to nitric acid.

And not only was that true of urea but also of most substances which were present in crude sewage. They must undergo a preliminary hydrolytic change which did not involve the absorption of any oxygen. Therefore, he contended that it was perfectly true to say that the first change was a hydrolytic change. Bacteriologists might quibble and say that it was not an anaerobic organism which was bringing about this change, and that, similarly, yeast which converted sugar into alcohol was an organism which lived in the air. It was forgotten that although the production of wine took place in the presence of air, when the yeast was breathing in the air it did not produce the change of sugar into alcohol. He maintained that it was only when the contact bed was acting as a septic tank or a hydrolytic tank that the sludge disappeared. Therefore, it was during the empty period that the oxidation was taking place and during the full period it was acting as a septic or a hydrolytic tank. As pointed out by Mr. Scott-Moncrieff years ago it was certainly advantageous to keep the processes distinct. With regard to the question of open tanks or closed tanks, that matter had been discussed over and over again. The gases which were evolved from the septic tank could be used for working a gas engine, to lift a certain amount of the contents of the septic tank on to the filter beds. How much, depended on temperature and condition. If their energy was sufficient to lift the tank effluent only a few inches they could do with practically no fall at all, by making the filter bed proportionally of larger area. The cover instead of being built of concrete, which leaked and was liable to cause explosions, should, in his opinion, be movable like that of a gas-holder. He made that suggestion some years ago, and he believed that some one had taken out a patent since for the idea, but he had never seen any plant in which the cover was made in that way. It must be very easy to construct, and very desirable, as the cover could be used to regulate the pressure of the gases. The gases came out so slowly, and at such a low pressure, that a cover of that description was very useful.

The survival of pathogenic organisms in effluents had been dealt with quite recently at the Brussels Congress, and he must say that he agreed with the author that it was impossible to expect, at any rate for many years to come, the idea of sterilising sewage effluent to be carried out. The problem was very costly, and he doubted whether Dr. Thresh had overcome the difficulty by means of his patent. Theoretically it was possible to sterilise the liquid, without producing any waste of heat at all, but practically it was impossible. He had had occasion, for some years, to study the plants for sterilising water by heat, and he found that they could not get an apparatus without some loss of temperature, and that loss of temperature would tell up when they had to deal with large volumes of sewage.

He had recently had to examine oysters from the mouth of the Thames and the Medway, many miles away from a sewage outlet, and there they had still contained coli organisms. It was almost impossible to find any water on the coast of England which was free from coli, even where there seemed to be no possible sewage contamination. Far remote from big populations and far in the sea, the coli organisms were still found, and the typhoid organism presumably could travel as far. He was of the opinion that it was not the duty of the sewage manager to sterilise his effluent. It was the duty of the watercress grower or of the oyster merchant, or the water purveyor, to see that their commodities were sterilised before being consumed.

Mr. E. J. SILCOCK said that he was in general agreement with the author of the paper. The two main points upon which the author expressed his opinion were that an anaerobic process in the purification of sewage was not necessary but was desirable, and that generally speaking continuous filters were preferable to contact beds. As an engineer he did not pretend to draw such fine distinctions as Dr. Rideal had done between hydrolising and anaerobic organisms, but he looked at the results obtained.

At a meeting of the Municipal Engineers, Mr. Scott-Moncrieff read a paper, and in the discussion which took place on the paper, he (Mr. Silcock) referred to the purification process which had been carried on at Leeds, in which crude sewage was applied to a continuous filter without previous septic treatment, and Mr. Scott-Moncrieff in his reply said, " Oh, yes, that is all very well, but the septic action had gone on in the sewer before the sewage was applied to the filter." He was prepared to admit that septic action might commence in the sewer or possibly even in the human body before the sewage reached the sewer, but what they, as engineers, wanted to know was whether the sewage could be dealt with by any process which did not involve previous septic treatment as a component part, and in his opinion the answer to that question must be in the affirmative.

They had absolute proof, from the numerous installations of double contact beds about this country, that sewage could be treated successfully by an aerobic system without a previous septic tank. In the system at Leeds the same process was being carried out by a continuous filter, and Dr. Rideal had said that in a continuous filter the process going on was an oxidising one. He would take him upon his own words. Therefore it seemed to him that Mr. Thudichum's argument was correct, and that it was not necessary to have a particular part of the process in which a septic action was going on. If that was admitted they could, he thought, all agree. They could agree that a septic process was desirable to assist subsequent filtration, because it would reduce the amount of solids to be settled or filtered out of the filter effluent, and hence works could be constructed at a cheaper rate than if they did not have a septic tank. But, on the other hand, there were circumstances in which it was very difficult to find a site upon which they could carry out a septic process, because there was a liability of unpleasantness arising from a septic tank, and in those circumstances it was valuable to be able to dispense with the septic treatment. He had at present before the Local Government Board a scheme of sewage purification in which there was no septic process. The scheme was a continuous filter, with subsequent sand filtration to take out the solids, and he believed it was the first of its kind submitted to the Board.

As to the advantage of a continuous or trickling filter as against a contact bed, the whole point appeared to lie, not in the bacterial question, but in the practical question of getting the solids through. He was of opinion that there were not in this country a contact bed which was not sludging up more or less quickly by the deposit of solids, whereas with a continuous filter, if the material of the bed were big enough, it was quite possible to wash the solids through, and the bed went on for an indefinite period. Therein lay the advantage of the continuous filter over the contact bed. But he was quite prepared to admit that there were other things to be taken into consideration in making the selection. The question of fall was most important. The 3 or 4 feet extra fall required for a continuous filter often turned the balance in favour of contact beds as against filters.

As to sea outfalls he agreed with the author that the Local Government Board could very well allow the local authorities to carry out purification systems which, though possibly not perfect, would be a very great improvement. In a great many cases if a septic tank were constructed to resolve the solids, and the effluent from the septic tank were allowed to be discharged into the sea, or even into a tidal river of large size, it would be all that was necessary. He had carried out one or two schemes in which such a system had given satisfactory results.

With regard to the application of septic effluent to land he knew that that point had been considered as disposed of. The Leicester experiments on that head had given such unsatisfactory results that many persons quite concluded that the system was unworkable. He contended, however, that the Leicester experiments had failed by reason of the land being unsuitable. Recent experiments had shown that with suitable land septic effluent could be successfully utilised. It was carried out on a large scale at Birmingham, and it had been carried out in other places. He thought that in that case, as Mr. Thudichum had put it, they were following the course of nature. Farm manure in a septic condition was put on land. Why should not septic sewage be put upon land? He was sure that a much larger quantity of sewage per acre could be dealt with in that way than would be possible where there was no septic treatment.

Mr. THUDICHUM said that he was thankful for the discussion which his paper had aroused. It had been very much on the lines that he expected and hoped for. They had been told by Dr. Thresh that a sprinkler effluent was absolutely superior to a contact effluent, and yet it had been said incidentally that a sprinkler effluent contained black suspended matter which had to be removed by subsequent filtration. He thought that he was fully justified in saying that the subject was still *sub judice*. They must not jump at conclusions, nor must they make up their minds that, because in one town a good result was obtained with one process, therefore no other process was worth considering.

Dr. Thresh certainly astonished him when he suggested shrimps as a means of conveying typhoid fever. Dr. Thresh, as a medical officer, would probably tell them that if they scalded their milk they would be free from the danger of typhoid infection from that source; and he (Mr. Thudichum) was not aware that shrimps were eaten raw. He believed that as a rule they were boiled. Dr. Thresh had talked of sterilising sewage by heat. As to that, one of the speakers had used some rather strong terms, but he (Mr. Thudichum) thought that they were justified. He had seen sewage at the Barking outfall running out into the river at the rate of over 300,000,000 gallons a day. He should like Dr. Thresh to start to sterilise that quantity of 300,000,000 gallons by heat. The thing was simply impossible.

Coming to Mr. Scott-Moncrieff's remarks, he was grateful to that gentleman because he had certainly proved one of his points most definitely and decidedly, for he had been very indefinite himself. That was the point that he (Mr. Thudichum) wished to make. It was that they should not be dogmatic about this matter. Many persons pretended to know a great deal about it, and possibly some of them did know a great deal, but they must not therefore conclude that other people did not know anything, and they must not conclude that because they were right other people were wrong. Both parties might be right.

November 30*th*, 1903.

J. PATTEN BARBER, PRESIDENT, IN THE CHAIR.

MECHANICAL STOKERS FOR ELECTRICITY GENERATING STATIONS.*

BY ALBERT GAY.

IT is almost unnecessary to remind you that from the days of James Watt until the present time, engineers all over the world have been ceaseless in their endeavours to bring about greater economy in the utilisation of energy; and so keen has become the competition towards this desirable end that the number of patents for appliances invented with this object in view probably amounts to many thousands, the greater portion of which not having fulfilled the expectations of the sanguine inventor, have sunk into oblivion. Amongst these, the records of our Patent Office include a large number of machines which, if they could operate successfully, would upset all our present ideas regarding the laws of the conservation of energy, and perpetual motion would be an established fact. We have of late heard a great deal about radium as an inexhaustible source of energy, but notwithstanding the gushing reports and brilliant forecasts of the daily press, the author prefers at present to pin his faith to those sources of energy to which he is accustomed, such as coal, rather than to radium. He proposes to confine his remarks in the present paper to the consideration of one of the many types of appliances which have for their object increased economy in the raising of steam.

In the generation of electrical energy, loss is taking place all along the line from the coal to the lamp, chiefly, however, in the boiler and engine, as will be seen in Table I. which the author has been able to reproduce by the kind permission of the editor of 'Power.'

Taking the calorific value of a pound of fair quality coal at 13,500 B.Th.U., it will be seen that less than 10 per cent. is delivered as mechanical energy to the dynamo. If therefore the full value of 13,500 B.Th.U. is obtained, only 1273 B.Th.U. are available for use by the dynamo. Unfortunately in practice it is only too often found that nothing like the 13,500 B.Th.U. mentioned are actually obtained even in the furnace, and given a sufficiently careless or incompetent stoker, the results may be very low indeed.

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* A Society's Premium was awarded to the author for this paper.

Table I.—Showing Loss from Furnace to Lamp.

——	Per Cent.	B.Th.U.
Ashes	1·00	135
Boiler radiation	5·00	675
Chimney Gases	22·00	2,970
Radiation in steam pipes	1·56	210
„ auxiliary pipes	·22	30
„ „ exhausts	1·40	190
„ engines	2·08	280
Loss in engine exhaust	57·31	7,737
Loss up to the engine	90·57	12,227
Balance (available energy)	9·43	1,273
	100·00	13,500
Loss between furnace and engine	90·57	12,227
Loss in engine	·56	76
„ generator	·36	48
Loss up to switchboard	91·49	12,351
Balance (available)	8·51	1,149
	100·00	13,500
Loss up to switchboard	91·49	12,351
Loss in distribution	1·24	167
	92·73	12,518
Total delivered to lamps	7·27	982
Total heat in coal	100·00	13,500

Perfect combustion is necessary to obtain the maximum value from the coal. The average boiler cannot be looked upon as an ideal apparatus for the economical generation of steam even when fired with the utmost care and skill, and indeed to obtain the highest calorific value from the coal, is a performance which can only be carried out under laboratory conditions. Tests carried out, however, under such conditions have given us with some certainty the thermal units which may be obtained from any given class of coal under varying conditions of combustion; and the more complete the combustion, the higher is the efficiency until perfect combustion is attained. The thermal value of coal and the quantity of air required in order to obtain perfect combustion are well known, and in the case of the coal previously mentioned having a calorific value of 13,500 heat units per pound, about 130 to 135 cubic feet of air is usually given as sufficient. In actual practice in a furnace, however, this amount would have to be largely exceeded, much depending upon the construction of the furnace, so that how to apply the knowledge experimentally obtained in the laboratory to the construction of a furnace so that ideal results may be depended upon has yet to be discovered. It is evident that a perfect apparatus of the kind would have to be entirely automatic, as the idiosyncrasies of the average human stoker would render the results unreliable even with the best designed and constructed apparatus.

While not even the most sanguine inventor could go as far as to say that his apparatus fulfils the ideal conditions, there is no doubt that excellent results can be and are being attained, and great credit is due to those whose inventive ingenuity has been the means of attaining these results under the adverse conditions inherent in an average electric power station, even when watched by workmen who are able and willing to give the machinery a fair chance. The main object in life of the average human stoker when firing by hand appears to be to crowd on as much coal at a time as the furnace will hold—the bigger the lumps the better—then to shut the door and trust to luck. The principle of stoking a little at a time and often, at the same time regulating the draught and keeping a clear fire, does not appeal to him. It is therefore not surprising that engineers should desire to replace the careless or incompetent stoker of the human variety with a machine of some kind which will even approximately fulfil the duties required of it. It is with this object in view that so many mechanical stokers have been placed upon the market.

An ideal mechanical stoker should fulfil the following main requirements:—

1. Increased economy in fuel when compared with hand-firing.
2. A smokeless furnace even with bituminous coal.
3. Few wearing parts.
4. Reliability.
5. Self-contained.
6. Small capital cost.
7. Small maintenance cost.
8. Small running cost.
9. Adjustable feed.
10. Automatic in action.

The various types of mechanical stokers derive their names from the methods adopted for feeding the fuel into the furnace. They may be divided generally under the following heads:— Over or top-feed, where the fuel is deposited above the firebars; and under-feed. The first type must be subdivided into two classes, viz.: (*a*) sprinkler; and (*b*) coker. In the first case the fuel is thrown or sprinkled in small quantities at a time all along the furnace, and in the second case the fuel is dropped on or near the dead-plate just inside the furnace door, and moved slowly forward by means of moving firebars, rams or other mechanical devices, so that the gases are given off slowly and consumed by passing over the clear fire ahead.

The under-feed type, as its name implies, feeds the fuel into the furnace from below the bars by means of rams or screws or similar devices. In this case it is obvious that the whole of the coal has to pass through the fire before it can reach the top.

The driving gear required to feed the fuel into the furnace, to oscillate or rock the bars in order to break up and remove the clinker, and also to regulate the quantity of fuel, varies in construction and application in different stokers. The main principles, however, are common to each type, so that a general description of any one of a type will, except in detail, convey a good idea of all.

Fig. 1 of the illustrations shows a longitudinal section of a portion of the mechanism of a Proctor's Sprinkling Stoker. By the action of the moving gear and a spring shovel and tappet, a small quantity of fuel is distributed to different parts of the fire, viz.: the back, middle and front. This is effected by the tappet having three different throws, the whole being adjustable without opening the fire doors. The fire-bars are of the movable type, so preventing the adhesion of clinker and keeping the air-spaces free. The clinker also by the movement of the bars is gradually shifted along and worked off the end of the bars into a clinker pit, from which it is removed when cold. The makers claim that they can regulate the quantity of fuel to be burnt by a simple adjustment of the regulating screw of the ram, which supplies fuel to the shovel from 2 cwt. per hour per furnace upwards. The shovel being made V-shaped throws the fuel out in the form of a fan, and so distributes it well up to the sides of the flues.

Fig. 2 shows a longitudinal section of mechanism of the E.S.E. stoker, made by the Smoke Preventer Company. It will be seen that this is also of the sprinkler type. A is the shaft carrying the fan or beaters; B, the fuel feed box which oscillates at right angles to the boiler front, and in doing so feeds the fuel from the hopper H through the opening above the fans, where it is caught by the vanes of the fan C, and projected into the furnace. Moving bars prevent adhesion of the clinker and carry it forward to the end of the grate where it is deposited and removed in the usual manner. In order to regulate the amount of fuel delivered to the furnace the stroke of the fuel feed-box B is increased or diminished. With a view to producing equal distribution of the fuel over the whole furnace deflectors or distributing plates are provided, which deflect the fuel in the direction required.

Fig. 3 illustrates a longitudinal section of a Vicars stoker. This is of the second class of the top-feed stokers, and is known as a coker, or coking stoker. The fuel is fed from the hopper into boxes from which it is gradually pushed by reciprocating plungers or rams on to the dead-plate. From the dead-plate it is pushed on to the moving fire-bars which slowly convey it to the rear of the grate. The partially consumed coke with the clinker and ash is discharged (as shown) over the end of the fire-bars into the flue, where they act as a bridge and prevent the passage of free air directly into the flue. The feed is regulated by altering the rate of motion of the plungers. The motion of the firebars can also be regulated.

Fig. 4 shows a diagrammatic section of the ram and hopper of the "Koker" stoker made by Messrs. Meldrum. The ram in this case is made in the form of a sector working on a pivot, and the makers claim that with this arrangement less power is absorbed than with sliding rams. The moving fire-bars have an undulating surface so that the reciprocating motion of adjacent bars prevents the clinker adhering. The air spaces are also very narrow, to prevent loss of fuel by passing between the bars into the ash-pit.

Figs. 5 and 5*a* show perspective views of the back and front ends respectively, of a chain-grate stoker, as made by Messrs. Babcock and Wilcox. The grate consists of an endless chain of short cast iron fire-bars linked together, and operated by passing over drums at either end, the front drum being revolved by a worm and worm wheel. The coal is fed over the whole width of the grate, and the thickness or depth of the fire is regulated by the adjustment of the fire-doors which are lifted vertically. This, added to the fact that the rate of travel of the grate can also be regulated, is claimed by the makers as fulfilling all the requirements for various classes of coal and varying demands of steam. It is claimed that it is entirely self-clinkering, and as the fuel is exhausted by the time it reaches the back end of the furnace, the ash and clinker drop automatically into the ash pit in the usual manner. The whole stoker runs on rails and can be brought out clear of the boiler if required for examination or repair.

Fig. 6 shows a longitudinal section of an under-feed stoker by the Underfeed Stoker Company. In this case the fuel from the hopper is carried under the bars by means of a screw, and is forced up through a cavity in the middle of the furnace and then slides down on either side of the sloping fire-bars; the clinker and ash accumulating at the bottom on either side of the furnace. The feed-screw as well as the bars are actuated by means of a small reciprocating engine on each stoker, so that it is self-contained.

The two tests of hand-firing and under-feed stoker firing respectively recorded in Table II., were conducted under the direction of the author.

TABLE II.

——	Hand-Firing.	Stoker.
Duration of test in hours	9	16
Coal consumed (in lb.)	8,372	9,218
Average per hour (in lb.)	930	576
Total water evaporated (in lb.) . . .	74,075	78,937
Total ash (in lb.).	780	1,474
Actual evaporation of water (in lb.) per pound of coal	8·84	8·56
Ditto at and from 212°	10·12	9·85
Average cost of coal per ton	18*s.* 9*d.*	11*s.* 4*d.*
Average percentage of CO_2	..	11·5
Calorific value of coal in B.Th.U. . .	14,200	12,800

TABLE III.

——	*a.*	*b.*	*c.*	*d.*
Duration of test in hours .	5½	8	..	6
Coal consumed (in lb.) . .	9,243	10,656	..	14,784
Average per hour (in lb.) .	1,760	1,332	No information.	2,464
Total water evaporated (in lb.)	92,000	108,760	No information.	116,850
Total ash (in lb.)	..	538	..	3,030
Actual evaporation of water (in lb.) per pound of coal .	9·95	10·20	..	7·9
Equivalent evaporation at and from 212° Fahr. . . .	11·96	12·39	11·3	8·8
Cost of coal (per ton) . .	..	..	..	..
Average percentage of CO_2 .	14·5	No information.	..	..
Calorific value of coal used in B.Th.U.	14,043	14,275	14,509	Smudge, say 12,000

The small quantity of coal consumed by the stoker does not mean that the evaporative capacity of the boiler is reduced, but that no forcing was attempted and the firing was slow, as the demand upon the boiler at the time was small. This is proved by the fact that in subsequent tests the consumption sometimes equalled 1000 lb. per hour. It must also be remembered that when forced, hand-firing would also show a greater consumption per hour.

Tests made with other stokers show the results recorded in Table III. These figures have been supplied by the makers.

In the foregoing, *a* and *b* were sprinkling stokers, and *c* and *d* were coking stokers. The average actual evaporation shown is for the three (*a b* and *d*) 9·35, but the calorific value of the coal used in *a* and *b* is higher than in the tests in Table II. for the stokers. It would therefore appear that with coal having a calorific value of from 12,000 to 12,500 B.Th.U. per lb., the average evaporation with mechanical stokers is somewhere between 8 and 9 lb., as shown in the test in Table II.

As regards the questions of reliability and cost of upkeep, the results are not always so satisfactory. The stokers under trial have been out of commission more often than is desirable, and the cost of maintenance is rather higher than the makers claim, amounting roughly to 10 per cent. per annum upon the capital cost.

Other devices not usually classed as stokers, but worthy of mention in this connection, are:—pulverised fuel furnaces; liquid fuel furnaces; and double grate furnaces.

In the first case the coal is ground up to an impalpable powder and is driven by means of compressed air through nozzles and is then set alight. By a proper regulation of the quantity of air admitted in proportion to the coal dust, it is claimed that very perfect combustion and consequently a high efficiency results. It must be remembered, however, that the coal has first to be reduced to dust by mechanical means; and as far as the author knows, there does not appear to be conclusive evidence that the cost of pulverising the coal and the risk attendant upon doing so, is not prohibitive. It is, however, too early to express an opinion, and theoretically at least the idea is a promising one.

The liquid fuel furnace is really a variety of that first named, and does not call for special comment. Instead of coal, crude hydrocarbon oil is forced into the furnace by means of compressed air, in the form of a fine spray, and then ignited. Economy and convenience are claimed for this apparatus. It has been suggested, however, that if largely adopted, the price of crude petroleum would probably rise rapidly, and so destroy the main advantage claimed.

The double grate furnace, as its name implies, consists essentially of two grates, one above the other. The upper one is formed of tubes expanded into headers at either end, the latter being connected to and forming part of the circulating system of the boiler. Upon this grate the fire is placed, the fuel being fed by hand through the fire-doors in the usual manner. The only direction that the draught can take is downwards, that being the only path to the flue. When the fire has fairly started, the small particles of incandescent fuel fall between the bars, or rather tubes, of the upper grate, into another grate below, and there accumulating form an incandescent bed which immediately consumes any gases which may come through from above unconsumed. It is claimed that the admission of cold air into the furnace after the fire has properly started is impossible except when the fires are cleaned, as all the air admitted when firing the top grate has to pass down through the fire, and the middle door is only opened very occasionally for cleaning purposes. There should apparently be very complete combustion, but it would appear that the circulation in the tubes of the top grate would have to be exceptionally good to prevent overheating, and it would be interesting to know what happens in practice when hard water is used.

The chief advantages claimed by the makers of all these appliances are practically the same, viz.:—

1. That there is more perfect combustion than is possible in any other way, and consequent economy.
2. That a lower grade coal can be consumed.
3. That a smokeless furnace and a clear fire is always possible even with bituminous fuel.
4. That the necessity of frequently opening the doors and admitting cold air with all its attendant risks and disadvantages is removed.
5. That there is a saving in labour.

It is interesting to note that one maker puts in as a special claim—"The fewness of the working parts and their extreme simplicity," while at the same time he issues a detailed list of "spare parts" each illustrated and numbered from 1 to considerably over 100, all or any of which it is assumed may be required to be replaced periodically.

As a set-off against the advantages claimed by all makers (they are of course unanimous) it is only fair to give some of the disadvantages claimed by some users, who are not unanimous in this respect. In this, as in every question connected with engineering matters, there is a divergence of opinion, and necessarily so, for no piece of machinery can possibly give identically the same results when run in a different place and under different conditions. All appliances must be selected to suit the conditions existing, unless it is possible or rather practicable to alter the conditions to suit the appliances. The disadvantages claimed by some users will therefore be no surprise to anyone, and are as follows:—

1. There is no economy.
2. Lower grade coal is not worth burning, and it smokes anyway.
3. Cost of upkeep is excessive.
4. In an electric power station the mechanical stoker has to be supplemented by hand-firing on account of varying load.
5. It is frequently out of order.
6. It reduces the capacity of the boiler.

The above represent the extremes of opinion for and against. It will be fairer perhaps to now give the opinions for and against of the chief engineers in some of the largest electric power stations in London and the provinces. Expressions of opinon were invited by the author in a series of questions, and they and the abbreviated replies are as follows, both being numbered consecutively.

QUESTIONS.

I. Have you had any experience with mechanical stokers in your work?
II. What type?
III. Are they satisfactory or otherwise?
IV. Principal defects, if any?
V. Are they still in use?
VI. If abandoned, for what reason?
VII. Additional information or expression of opinion.

REPLIES.

London Stations.

No. 1.

Question I. Yes, 4½ years. II. Top feed. III. Otherwise IV. Less economical than hand-firing. Maintenance costs heavy. Boilers could not be forced to same extent as with hand-firing. Not smokeless. V. No. VI. Reasons given above. VII. Mechanical stoking does not pay in London, as a large proportion of the cost is swallowed up in carriage. Probably a saving may be effected if coal can be obtained at not more than 7*s.* 6*d.* per ton delivered.

No. 2.

Question. I. Yes, over 2 years. II. Top-feed. III. Otherwise. IV. Not as economical as hand-firing. Did not prevent smoke. Unreliable. Upkeep expensive. V. No. VI. Reasons given above. VII. In London it pays to use the best coal you can get on account of high charge for carraige, and this does not do for mechanical stokers.

No. 3.

Question I. No, cannot recommend them.

No. 4.

Question I. No.

No. 5.

Question I. Yes, but only recently. Have given satisfaction up to now.

No. 6.

Question I. No.

No. 7.

Question I. No.

No. 8.

Question I. No.

No. 9.

Question I. No, as from previous experience and that of others, I find they are usually abandoned after two or three years, or some shorter period.

No. 10.

Question I. Yes, several years. II. All types. III. All have given trouble, none are perfect. IV. Not specified. V. Most of them. VII. When working at full capacity, satisfactory, but with fluctuating loads prefer hand-firing. More efficient than hand labour, as it requires less wages and does not strike.

No. 11.

Question I. Yes. II. Both top and underfeed. III. Otherwise.

No. 12.

Question I. Just experimenting.

No. 13.

Question I. Yes, two years. II. Top feed. III. Yes. V. Yes.

No. 14.

Question I. Yes, but not long. (No information.)

No. 15.

Question I. Have tried several, but have none in use now.

No. 16.

Question I. Yes. (No information.)

No. 17.

Question I. Yes. II. Top feed. III. Fairly satisfactory. IV. Cannot force on load. V. Yes. VII. Type of stoker should suit class of coal.

No. 18.

Question I. Yes, 1½ year. II. Top feed. III. Entirely satisfactorily. IV. No defects whatever.

No. 19.

Question I. Yes. II. Top feed. III. Yes. IV. (1) Liable to smoke; (2) heavy repairs.

No. 20.

Question I. No.

No. 21.

Question I. Yes. II. Under-feed. III. Otherwise. IV. Uneconomical, smoky, unreliable. V. No. VI. Reasons given. VII. Mechanical stokers not necessary in London, and do not pay for the capital invested in them.

Provincial.

No. 1 (on the coal fields).

Question I. Yes. II. Top feed. III. Satisfactory. V. Yes. VII. Average price of coal, 7*s.* 3*d.* per ton.

No. 2 (on the coal fields).

Question I. Yes. II. Top feed. III. Quite satisfactory. IV. No material defects. V. Yes. VII. 9*s.* to 10*s.* per ton, coal used washed slack and washed peas.

No. 3 (not on coal fields).

Question I. Yes, 3 years. II. Top feed. III. Otherwise. IV. (1) Limited the output of the boilers; (2) evaporation duty low; (3) high cost for maintenance (frequent renewal of parts). V. No. VI. For reasons given.

As already stated, the opinions differ, and while it would apparently be obvious that on or near the coal fields, mechanical stoking would be almost essential, there appears to be a doubt as regards London.

It must be remembered that a fair grade of coal, say of 13,000 to 14,000 B.Th.U. per pound would cost in Wales or in the north of England at the pit's mouth say 8*s.* or 9*s.* per ton; by the time it arrived in London its cost will have doubled, while its calorific value remains the same, or perhaps a trifle less. The cost per ton must now be taken as from 16*s.* to 18*s.*, made up equally of intrinsic value and rail carriage. Now suppose we take a low grade of coal, having say a calorific value of 11,000 or 11,500 B.Th.U. per pound, which may cost, say, 5*s.* or even 4*s.* at the pit's mouth. By the time it reaches London, the cost has gone up to 12*s.* or 14*s.* per ton, made up of 4*s.* or 5*s.* intrinsic value and 8*s.* or 9*s.* rail carriage. It would appear that it is the wisest course to pay for heat units rather than for rail carriage, and that therefore the higher the grade of coal burnt in London, the greater would be the resultant economy. The question is a debatable one and is worth ventilating, and it is hoped that expressions of opinion upon this point may be freely given by those present. It will be seen that two engineers in their replies give diametrically opposite opinions upon this question.

The author desires to thank those gentlemen who have so kindly assisted him by lending him lantern slides, diagrams and models. He also desires to express his deep appreciation of the honour conferred on him in being permitted, as a non-member of the Society, to contribute to its Transactions the present paper. He further begs to tender his sincere thanks to his old friend and colleague, Mr. J. Patten Barber, the esteemed and able President of the Society, for his kindness in inviting him to prepare and read a paper upon a subject of such importance to all electrical engineers.

The following communication from Mr. B. D. Healey, who was unable to be present, was then read by the Secretary:—

The subject of Mr. Gay's paper is of considerable importance, but from a truly economical point of view, the ideal stoker suggested by the author has yet to be found. Were it not for legislation for the prevention of smoke, the use of mechanical stokers would have been discontinued long ago, and the proportion of mechanical versus hand-stoked furnaces, would now be very acceptable information.

The question of available energy from fuel used, has really been quite a secondary matter since smoke inspectors were invented, and some of the author's statements indicate that steam boilers in electricity stations will very soon be obsolete.

Thirty-three years ago the late Sir William Siemens tried firing boilers with producer gas, and I erected a large number of plants at ironworks in Scotland, under the most favourable conditions for obtaining reliable results. The loss from radiation up to the boilers was 23 per cent., and at the boilers 5 per cent., which coincides with the three leading items of Table I., by the author, and these losses are nearly uniform in every system of solid fuel firing. There was a marked convenience in the means of regulating the supply to meet the demand for power, and there was absolutely no smoke. The cost of maintenance was very small, but there was not any saving whatever, as compared with fuel used in hand-stoking.

The near future will see a great advance in the use of power-gas for generating electricity, as the advantages, as regards capital outlay, convenience of regulating the supply, and the cost of maintenance, are altogether greatly in its favour. The lowest works-costs at present for generating per B.T.U. are as follows:—

Steam driven plant in coal fields . .	·69 of a penny
„ „ „ in central stations .	·90 „
High pressure power-gas driven plant .	·70 „

The latter gas is high in carbonic oxide, and low in hydrogen, which makes it the most desirable, and the nearest approach to blast furnace gas. The whole apparatus in the latest designs is nearly automatic, and there is no risk of explosions as in a steam plant.

DISCUSSION.

The President, in moving a vote of thanks to Mr. Gay for his paper, said that this was not the first time that Mr. Gay had favoured the Society. During the summer the Members had a very pleasant and instructive visit to the Islington Electricity works; and on that occasion Mr. Gay showed them over those works, and by the information he imparted he made the visit pleasant and interesting. They would remember the invitation which Mr. Gay gave to Members of the Society who at any time wanted to see the works or obtain any information. He was sure that Mr. Gay did not give that invitation merely as a matter of form. He had known Mr. Gay for many years, and worked side by side with him, and he knew that if Mr. Gay could help any engineer who was in need of a little friendly advice he was willing to give it. They were much indebted to Mr. Gay for having in the midst of a very busy life managed to prepare for them such an excellent paper as that which he had just read, and to accompany it with so many drawings and illustrations.

The vote of thanks was carried unanimously.

Mr. J. H. Rosenthal said that the paper was of the practical character which he had expected from Mr. Gay, who had put the question of mechanical stoking in a very concise way, and it would be almost suitable as a text-book on the subject.

Whatever form of stoker was employed mechanical stoking was at present a necessity, and engineers should address themselves to improving the methods of mechanical stoking which they had to do with. In a great many cases, engineers who worked mechanical stokers did not give sufficient attention to them, and unfortunately the machines worked under very disadvantageous conditions. In a large plant the question of labour, irrespectively of the question of the use of cheap coal, came to be a most important one. In these days boilers assumed such a large size that it was quite impossible to fire them mechanically under any proper conditions at all. They could fire a Lancashire boiler evaporating 6000 or 7000 lb. of water per hour by hand, so that it would compare very favourably with one which was machine fired; but if they had a boiler which was to evaporate 20,000 or 30,000 lb. of water per hour, the question became quite a different one. It required more than the capacity of one stoker to fire a boiler of that size, and, if one man could do it, it would be found that one door was always open, and the boiler would be subject to a continuous inrush of cold air, which would interfere with its working.

In the plant which was being put down in the power house of the District Railway, which would probably be the largest power house in England, there would be 64 boilers, each evaporating 20,000 lb. of water per hour, and 128 mechanical stokers. It was reckoned that each eight boilers would be stoked by one man, and have one man to look after the water. In hand-stoking, one man would be required for each boiler, and as the boilers would be running all night, three shifts of men would be wanted in the twenty-four hours. The saving of labour in consequence of the use of mechanical stokers was an important point.

In the City of London Electrical Works, it would be absolutely impossible to run with hand-firing. Small stations could be run with hand-firing, and in such cases he would not recommend putting in a mechanical stoker, unless it were essential for the purpose of avoiding smoke, but in large plant the mechanical stoker was an absolute necessity. It then became a question of doing the best they could with machine stokers, which, by reason of the conditions under which they worked, were difficult to make perfect.

Mr. Gay had unfortunately got very unsatisfactory replies to the letters which he sent out, and at that he (Mr. Rosenthal) was rather surprised. The Corporation of Exeter before adopting chain-grate mechanical stokers made enquiry of some thirty electrical works throughout the country where those appliances were in use, and all the replies were favourable.

Many of the stokers which had been put on the market were brought out by makers, who did not really understand the working conditions. The conditions in electric lighting works were far more severe than those in mills, and a stoker which would answer in the latter might be unsuitable in an electrical station.

He should be very glad to be rid of mechanical firing altogether, but under the present conditions of electric lighting and power works it was an absolute necessity; and he should be very glad if somebody would invent a stoker more efficient than any which now existed.

Mr. Gay had been good enough to exhibit some efficiency tables. It was deplorable that such a small amount of the energy of the coal was transferred into useful work, but improvements were continually being made in that respect. There were boiler plants put up nowadays from which could be got fully 85 per cent. of the heat of the coal; and there were also engines which would run with 10 lb. of steam. That would give results a great deal more favourable than those shown by the figures given by Mr. Gay. Such refined plant might not be possible in every case.

With respect to Mr. Healey's letter which had been read, he was not prepared to admit that there was such a wonderful future in gas as he supposed. He (Mr. Rosenthal) made an experiment years ago in producing gas and firing it under boilers, and he came to the same conclusion that there was not any saving in it, although it had the advantage of avoiding smoke. The large gas engine was, he believed, capable of being used in cases where the gas cost nothing, as, for instance, in blast-furnace plant; but where gas had to be produced from coal he did not think that gas engines would ever sucessfully compete with the best practice in steam engines.

Mr. W. H. Booth called attention to one point with regard to mechanical stokers which he thought Mr. Gay had overlooked, and that was that when the coal was put on the front end of the bars of the stoker a great deal of combustion took place before the coal got to the back end of the bar, and the fire became thin. In the Vicars stoker that was got over to a very large extent by means of a very short grate, and by allowing the coal to burn away at the back of the bridge beyond the grate in a sort of gas producer pit. In the Under-feed stoker the difficulty was got over by bringing the coal up in the middle of the grate, and allowing it to fall, by the combined action of the oscillating bars and of gravity, to the side of the grate; so that where the fire became thin the coal would move down the bar by gravity. To perform that duty in America they took advantage of the force of gravity and of a vibrating grate set at a steep angle, and that caused the coal to pack gradually down to the lower end of the grate and prevented an enormous amount of cold air getting through the bars. It was only those stokers in which that point was attended to which could be successful and would give a large percentage of carbon dioxide in the gases. Suppose they took the chain-grate stoker, that possessed that defect. It was, otherwise, one of the best stokers there was, for the grate was always clean. The grate carried the coal in, and the coal burnt out before it got to the back of the furnace. The result was that an enormous amount of cold air got in.

Mr. Rosenthal appeared to be seeking for a perfect mechanical stoker. He should adopt the method of Mr. Eckley B. Coxe, who used a chain stoker and fitted beneath it a series of air-boxes. Air was drawn by the ordinary draught or forced by the fan into one division. It went from the first box into the second, and so to the end. The boxes were thus supplied with a diminishing volume of air, corresponding with the diminishing thickness of the fire on that part of the grate above each box respectively. The air went beneath the grate, and all the air was shut out from the grate except what would pass from the first box into the second, and so on. Without some such air regulation the horizontal chain grate could never prove economical.

Mr. W. E. Gower said that one difficulty which had to be contended with, with regard to mechanical stokers, was, that sometimes when a machine of that kind was put into a generating station or other boiler-house it was left to take care of itself. He did not say that that was so in every case, but in most cases the mechanical stoker was neglected more than any other machine that he knew of, and consequently it suffered. He thought that it was pretty well conceded at present that there was not a greater economy in the use of gas than in the ordinary firing of a boiler. There was an economy in a large generating station only where the residuum came into play. It was possible that if they were getting 25 per cent. residuum, and they were only losing 15 per cent. in economy, gas producers were economical. He thought that if gas producers became fairly universal, residuums would get to low values, and then it might possibly be thought advisable to fit gas producers with efficient mechanical stokers.

Mr. F. G. WATKINSON said that for some years he was in charge of large works where a great deal of steam was used. They belonged to a commercial firm, which wanted to show a balance on the right side of their ledger; and they had gone into the question of fuel economy, and the consequence was that to-day they were producing steam cheaply.

Up to about twenty years ago that firm had all Lancashire boilers, and the stoking was done by hand, Welsh coal being used at about 25*s.* per ton. Then the Vicars stoker was adopted, and at once showed a great reduction in the cost of producing steam; not because there was any less labour employed, but owing to the reduction in the coal bill—which was equal to about 40 per cent. After a time it was found that the mass of fire at the end of the furnace, lying in the tube, had a detrimental effect on the rivets; but, by adopting a conical bridge, that was remedied, and the stokers worked successfully for many years.

So far as his experience with mechanical stokers went, he had found that the chain-grate stoker required a much larger coal than the Vicars stoker. That was owing to the movement of the bars acting as a sieve, so that all the small coal fell into the ash-pit without doing any duty. He was also of the opinion that a greater draught was necessary with the chain-grate than with the Vicars stoker. During the past three years he had had twenty-three of the underfeed stokers under his charge, and so far the result had been satisfactory, and he was paying less per ton now than ever he did.

He carried out a few experiments with various coals on the underfeed stokers, and to his surprise he found that the cheap small coal evaporated as much water as the more costly and larger coal. That was also proved by one of Mr. Gay's charts.

One advantage about the underfeed stoker was, that there were no fire-bars or ash-pit, consequently all the coal, however small, went into the fire and was consumed; and there was no doubt that with that type of furnace there was less smoke. The difficulty in furnaces of other types was, too much coal was put on at a time and that the furnace door was always being opened, whereas a furnace of the underfeed type could be run five hours without the furnace door being opened. He found the steam motor supplied with the underfeed stoker to be very troublesome, and on no account would he recommend a motor to every furnace; the better plan, where there was a battery of boilers, was to have an engine to drive the entire set.

Mr. Charles Erith said that Mr. Gay had referred to the value of mechanical stokers in London. His (Mr. Erith's) opinion was, that with mechanical stoking even the best class of coal could be economically burnt. It was a matter of figures as to whether or not it would pay to buy cheaper coal of lower calorific efficiency. It was necessary to investigate each case on its merits. The great question was that of draught. The capacity of mechanical stokers depended very much on the draught. If the combustion was improved, it was done by admitting a lesser volume of air; and consequently the velocity of the gases was reduced, and more heat was transferred to the boilers. The better the combustion, the lower the chimney temperature and the lower the natural draught of the chimney. He considered mechanical draught to be a vital necessity in connection with mechanical stoking. It was perfectly easy to regulate mechanical draught automatically, and thus to get a constant proportion of air to suit the varying range of combustion. A mechanical stoker of proper design could be made to give satisfactory results, as combustion was purely a matter of bringing the requisite proportion of air and fuel together, which was quite an easy matter. With a proper draught they could get equally efficient combustion at different ranges of capacity.

Mr. Edward A. Harman said that the subject of mechanical stokers was one of vast importance, not only to electrical engineers, but to all engineers. Recently, he had visited numerous electrical installations, and other works where mechanical stokers, applied to all sorts of boilers, were in use. He had seen many mechanical stokers out of use, or being largely assisted by handwork. Of course, it would be readily admitted there were many excellent mechanical stokers extant, but there were also many defective ones.

With regard to the latter class, their chief value consisted in the price they would eventually realise as scrap metal. That was evident from the number of installations where hand-firing was frequently resorted to, and the undue number of stokers which were to be found, if not superseding the mechanical stokers, at all events materially assisting in their operations.

He thought Mr. Gay's paper would be valuable as a work of reference upon the subject. Mr. Gay had laid before the Society a large amount of interesting information which could hardly be digested in the short time of a meeting. It would therefore be all the more valuable as a permanent record in the Transactions of the Society.

As a representative of the gas engineering profession, he had listened in vain for any due appreciation of the value of gas engines as applied to electrical installations. It was generally known that gas engines had not taken their right place in electrical stations, but he felt convinced that that would be gradually corrected; more especially as Parliament was assisting in the matter by authorising gas of a lower illuminating power, and therefore cheaper than formerly, to be distributed. During the past few years a revolution had practically taken place in respect to that. It would be beside the question before the meeting to enter into the subject of gas engines, but he felt convinced that the near future would witness the adoption of gas engines in conjunction with electrical installations, either partially or wholly. Many gas engines required only 15 cubic feet of gas per H.P. per hour, which at 2*s.* per 1000 cubic feet represented only one-third of a penny. Many small electrical installations were successfully working at the present time with gas engines.

Mr. PERCY GRIFFITH said that he was one of those who had the pleasure of visiting the Islington Electricity Station in September last, and he should like to take the present opportunity of expressing his appreciation of Mr. Gay's interesting pilotage on that occasion. Among the many things Mr. Gay showed them was a mechanical stoker at work, but which was not illustrated in the paper. It was one which he believed could be worked either by hand or automatically. Mr. Gay had not, however, given them his experience with that particular apparatus, either in the paper or at the works, and he (Mr. Griffith) could only presume that Mr. Gay was reserving the information for his reply to the discussion.

THE PRESIDENT said that he was sorry that he could not invite any more gentlemen to take part in the discussion, as the time allotted to the meeting had expired. The Society would, however, be pleased to receive remarks in writing from those who were prevented from speaking through lack of time.

Mr. ALBERT GAY, in replying to the discussion, said that Mr. Rosenthal and another speaker had hinted if not stated absolutely, that they were unfavourable to mechanical stokers. He wanted to remove that impression immediately. He had already shown very clearly in the paper that the efficiency was very much higher in mechanical stoking than in hand stoking with the same quality of coal. He had shown that with coal of 18*s.* 9*d.* and 11*s.* 4*d.* a ton respectively, virtually the same amount of water was evaporated in each case. That showed a clear saving. The only unfavourable suggestion that he had made, was a suggestion of unreliability; and that was one which, from his own personal experience, he was not prepared to withdraw. It must be remembered that the paper dealt with, and his remarks were confined to, electricity generating stations. He was quite in accord with Mr. Rosenthal's suggestion that if it was necessary to put down very large plant, mechanical stoking would be a *sine qua non.* He did not think that in such a case hand-firing could possibly be as economical as machine stoking. No ordinary human stoker would attain the efficiency of a mechanical stoker. All he wished to see was some improvements in the mechanism, or in the means by which the appliances were operated, both as regarded their liability to break down and the cost of up-keep, and a reduction in the time necessary to find spare parts to put in when they went wrong.

With regard to Mr. Booth's remarks, he thought there was undoubtedly something in what he said respecting the thinness of the fire at the end of the grate, but thought that he could safely leave Mr. Booth in Mr. Rosenthal's hands; and he had not the slightest doubt that if those two gentlemen would confer together they would bring out an ideal stoker in a short time.

With regard to the remarks of Mr. Gower, he (Mr. Gay) was quite certain that any appliances that were put in at the Islington Borough Council's Electricity Works had received impartial treatment. A great deal of the comparatively small trouble which had occurred in connection with mechanical stokers at the Islington works, had been due to the makers' own fault in not supplying them with new parts, to replace those broken, for two or three months. It was not neglect of the people who ran the stokers so much as the inability of the contractors to replace broken or worn out parts in a short time. From that cause the stokers had been left out of commission longer than was necessary.

He thought that Mr. Watkinson, also, could very well be left to Mr. Rosenthal. It would be advisable for Mr. Watkinson and Mr. Rosenthal to meet together, and perhaps if Mr. Gower joined them they would make a good trio.

As to Mr. Charles Erith, he had been good enough to refer to the vexed question of whether or not they should use coal of a high quality or a low quality in a mechanical stoker; and he (Mr. Gay) was pleased to see that that gentleman's remarks agreed very well with his own ideas. He had been met with an objection which he thought raised a serious difficulty: viz. that if coal of say 13,000 to 14,000 British thermal units per lb. calorific value was used, the temperature in the boiler would become dangerously high. Under the circumstances he should take the first opportunity he had of making some experiments with different qualities of coal in a mechanical stoker. To the best of his knowledge, his paper applied to nearly every type of stoker which had been put upon the market, including that of Mr. Charles Erith at the Islington works. That stoker had been running alongside a stoker of the same kind by another manufacturer, and there was not very much to choose between them as regarded efficiency and everything else.

Mr. Harman had been good enough to say that the paper was important to all engineers. He wanted to call his attention to the fact that it was intended to apply to electrical engineers. He did not know the conditions which affected ordinary manufacturers, but he knew the conditions which applied to an electric lighting station. With regard to gas, he could only say that he should be delighted to recommend his council to try gas when there had been a little more experience of its use. He had a rather hopeful feeling with regard to gas. It was just possible that good results might be obtained, either by producer gas or gas of some other form, and he had no doubt that with proper appliances much might be done with gas in the future. One great advantage would be, that with gas the engine would occupy only about half the space now required by engine and boiler.

He was extremely obliged for the very kind expressions of thanks which the meeting had given to him. He only hoped that the question of mechanical stokers would not be allowed to drop, but that the matter would be thoroughly ventilated; and that ultimately they would get results even better than those which had been already attained.

The following letter, dated December 7, 1903, was received from Mr. C. Newton Russell, chief electrical engineer to the Borough of Shoreditch, subsequently to the Meeting :—

Want of time prevented me saying anything at the meeting on Monday last, and I now therefore submit the following remarks on Mr. Gay's paper.

It certainly was a surprise for me to notice that the greater portion of replies to the author's question were dead against automatic stokers of any kind, and I must confess that a few years ago I had a very poor opinion of them myself. However, I have now had about two years' experience with the chain-grate stoker, some of which type we have running at our Whiston

Street generating station, and so far my experience proves that automatic stoking is far more advantageous than hand-firing.

I find that all the advantages claimed by the makers are more or less gained, and that the disadvantages enumerated have not been experienced. In considering the matter of economy, the author apparently loses sight of the fact that it is possible to purchase small but bituminous coal in London, with a calorific value of only about 15 per cent. less than first class Welsh coal, the price of the small coal being about 40 per cent. less. I therefore submit that this point is worth the consideration of all station engineers; a number of whom have, of course, already grasped this fact, and are now using practically nothing but the cheaper quality of coal.

I have to thank Mr. Gay for bringing forward a paper on such an important subject.

The following is Mr Gay's reply to Mr. Russell's letter:—

Mr. Russell's remarks only corroborate the opinion expressed by me in the paper, my statement being as follows: "In this, as in every question connected with engineering matters, there is a divergence of opinion, and necessarily so; for no pieces of machinery can possibly give identically the same results when run in a different place and under different conditions." And it may interest Mr. Russell to know that nearly all the replies received from station engineers came to hand during the summer of this year, and therefore are up to date. Some of the replies, both favourable and otherwise, refer to chain-grate stokers.

In the last paragraph but one of my paper, is the following sentence: "It would appear that it is the wisest course to pay for heat units rather than for rail carriage, and that therefore the higher the grade of coal burnt in London the greater would be the resultant economy." Although prices of coal are given in the previous sentence, they are merely illustrative, it being assumed that, everything else being equal, a high grade coal will cost more than a low grade from the same district.

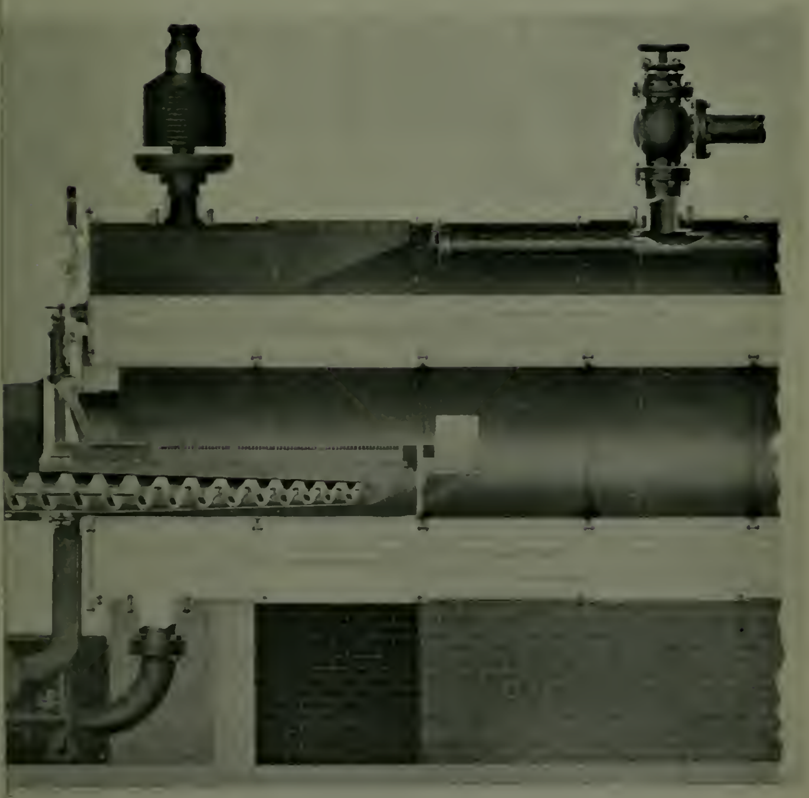

FIG. 6.

STOKERS FOR ELECTRICITY GENERATING STATIONS.
BY ALBERT GAY.

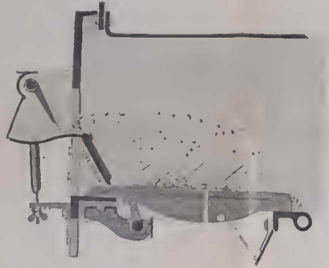

Fig. 1.

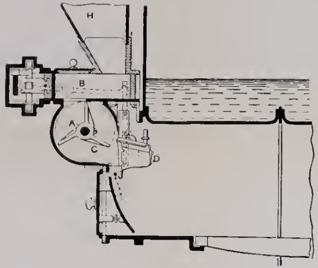

Fig. 2.

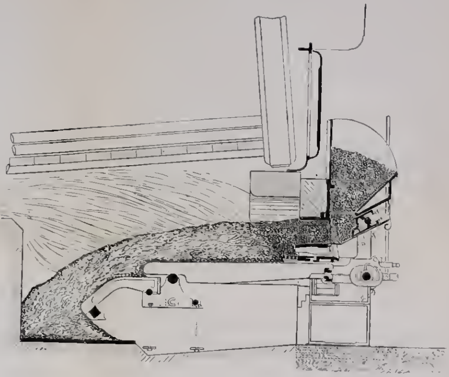

Fig. 3.

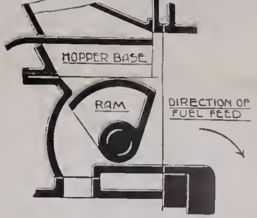

Fig. 4.

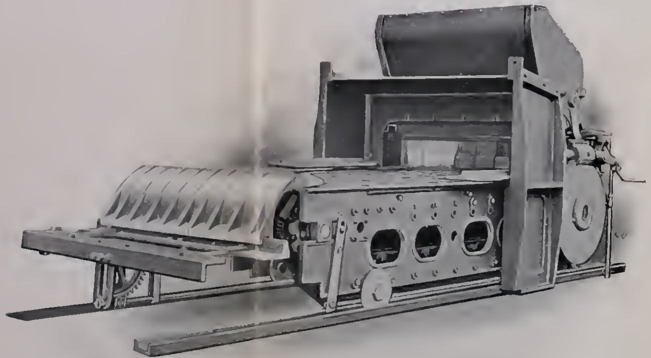

Fig. 5.

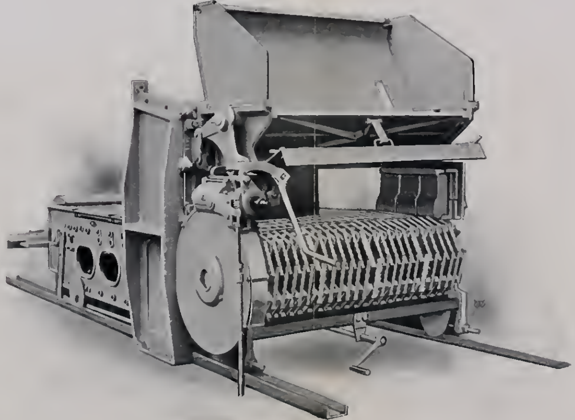

Fig. 5A.

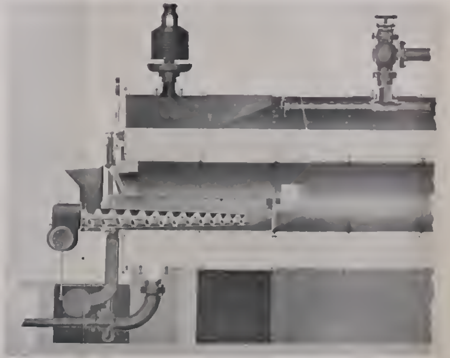

Fig. 6.

Obituary.

William Daniel Bayliss, whose death occurred on June 29, 1902, but was not reported until February 20, 1903, was born in 1841, and received his professional training under his father, who was a civil engineer. On leaving his father's office he obtained a Government appointment in Singapore, where, for nineteen years, he was engaged in the construction of bridges, piers, canals, sea walls, and the Singapore Waterworks. He was then appointed acting colonial engineer for the Straits Settlements, which position he occupied for six years, at the end of which time he retired from the service. Mr. Bayliss was elected a Member of the Society in 1876.

Lionel Norman Galbraith, who died at Obuassi, Ashanti, West Africa, on June 4, 1903, from exhaustion following an attack of blackwater fever, was the youngest son of Mr. A. W. Galbraith, C.E., of Southampton, having been born on May 21, 1880. He was educated at Winchester, subsequently attending the London Polytechnic, Regent Street. He was then articled to his father, and during that time was engaged upon several works in the south of England connected with his father's private practice. In November 1900 he was appointed a junior assistant engineer, under the Crown Agents for the Colonies, upon the Gold Coast Government Railways, Messrs. Shelford and Sons, of Westminster, being the consulting engineers, and was employed on the Sekondi-Tarkwa section. In December 1901 he was specially attached to the Lagos Nigeria Railway Extension survey party, under Mr. W. Gee, M.Inst.C.E. This expedition proceeded up the River Niger as far as Jebba, to select and survey a possible site for a bridge; and, that being found, to run a reconnaissance survey from thence to Horin in Northern Nigeria, to connect with the survey of the previous season. Owing to the satisfactory nature of his services he was promoted to the higher grade of assistant engineer, and at the time of his death was engaged in that capacity on the Kumasi Extension of the Gold Coast Railways. He was elected an Associate of the Society on November 3, 1902; and on February 4, 1903, he was admitted to the Associate Membership of the Institution of Civil Engineers of Ireland.

He was but 23 years of age, and a young engineer of exceptional promise.

William Edward Baker, who died very suddenly on July 27, 1903, was born in 1854, and entered the works of Messrs. Stone and Co., mechanical engineers, of Deptford, as an assistant in 1882, and with which firm he remained for fifteen years. He then became one of the founders of the firm of Ham, Baker and Co., of Westminster and Langley, Worcestershire; and, when the business was converted into a limited liability company, he was the first chairman of the company and one of the managing directors. He was a very successful business man, and one universally esteemed by the numerous engineers with whom he was so continually brought into contact.

Charles William Carrell, Major, 16th Middlesex Regiment, met with a tragic end on August 13, 1903, at Shorncliffe camp. The deceased officer was hurriedly putting away his revolver while dressing for mess, when a charge was accidentally fired; the bullet entering his body, and causing his death on the following day during an operation for its extraction. Major Carrell was born in 1854, and was elected an Associate of the Society in 1893.

Thomas Forth Rotheram, who died suddenly on September 11, 1903, at Perth, West Australia, was born in 1850, in Yorkshire. He commenced his early training in the Manchester, Sheffield and Lincolnshire Railway works at Gorton in 1865, and subsequently entered the service of the North British Railway Company, Glasgow. He afterwards took a position with the London and Glasgow Ship Building Company, for the purpose of gaining experience in the fitting and completion of the engines and boilers of several large ocean steamers. He then returned to the North British Railway, and was appointed to take charge of the erection of indoor and outdoor machinery plant. Subsequently he spent three years with Messrs Ransomes and Rapier, railway engineers, where he was engaged in the design and manufacture of fixed plant for railways in various parts of the world. While with this firm he was offered the position of locomotive and traffic manager on the New Zealand Railways, which he accepted in 1875, and subsequently he filled the following positions in that colony: general manager, Picton Railway, 1875 to 1878; general manager, Wanganui, Foxton and New Plymouth Railway, 1878 to 1885; locomotive superintendent, Hurunui-Bluff Railway, 1885 to 1888; and locomotive superintendent of the New Zealand Railways from that date up to

April 1900, when he accepted the appointment of chief mechanical engineer on the Western Australian Railways, in succession to Mr. R. B. Campbell.

While in the service of the New Zealand Government, he introduced in the railway workshops the complete manufacture of locomotive and other rolling stock. In 1887, while still connected with the New Zealand Railway, he was specially appointed by the New South Wales Government to report upon the railways and tramways of that state. In 1891 he was appointed by the New South Wales railway commissioners to enquire into the merits of the application of Westinghouse and vacuum brakes to goods trains. In 1892, under instructions from the New Zealand railway commissioners, he visited America and Europe, to make a personal examination and enquire into the working of compound locomotives; to enquire into the feasibility of placing electric motors on a portion of the New Zealand railways, and generally into the questions affecting electric welding, locomotives, machinery and lighting. Mr. Rotheram was elected an Associate of the Society of Engineers in 1873, and was transferred to Membership in 1885. He was a Member of the Institution of Civil Engineers and of several other professional societies.

JOHN ALLSOPP, who passed suddenly away on November 2, 1903, was born in 1848 at Milford, Derbyshire. After serving his articles with a civil engineer, he was appointed second engineer for the construction of the Erewash, Butterley and Ambergate Railway, and he was also concerned in the construction of the Settle and Carlisle Railway. In 1878, Mr. Allsopp was appointed engineer and surveyor to the old Local Board of Worksop, in which capacity he carried out the present sewerage system. At that time the town surveyor was allowed to take private practice, and this department of Mr. Allsopp's work so increased that in 1884 he resigned his public office and devoted himself to his own practice as architect and surveyor. He was the first engineer to the Worksop Waterworks Company, a position which he held till his death, and his services in that direction were sought by a number of private clients. Mr. Allsopp was elected a Member of the Society of Engineers in 1882. He was also a Member of the Institution of Mechanical Engineers and an Associate Member of the Institution of Civil Engineers.

FORTY-NINTH ANNUAL GENERAL MEETING

HELD AT THE OFFICES OF THE SOCIETY, 17 VICTORIA STREET, WESTMINSTER.

Monday, December 14th, 1903.

J. PATTEN BARBER, PRESIDENT, IN THE CHAIR.

THE Minutes of the Forty-eighth Annual General Meeting, held December 8th, 1902, were read, confirmed and signed.

The president appointed Mr. Alfred Burgess and Mr. H. Glynn Warne to act as scrutineers of the balloting lists for the election of the council and officers for 1904.

The president then announced the premiums which had been awarded by the council that evening, for meritorious papers read during the year (see the Report of the Council, page 236).

The scrutineers handed in their report of the results of the ballot, and the president announced the names of the gentlemen who had been elected as the council and officers for 1904. (For list, see commencement of this volume.)

A vote of thanks to Mr. Burgess and Mr. Warne for their services as scrutineers was passed, and duly acknowledged by those gentlemen.

A vote of thanks to the president for his services during the year was unanimously passed, and duly acknowledged by Mr. J. Patten Barber.

A vote of thanks to the vice-presidents, council and officers for 1903 was unanimously passed, and was acknowledged by Mr. D. B. Butler, President-elect.

A vote of thanks to the secretary was unanimously passed, and was acknowledged by Mr. Perry F. Nursey.

Mr. Burgess suggested that some special effort should be made to emphasise the year 1904, as being the fiftieth year of the Society's existence. It was decided to refer the suggestion to the status committee.

ANNUAL REPORT OF THE COUNCIL, 1903.

In reviewing the progress and work of the Society during the past year, the Council have much pleasure in recording a material advance in the membership. On December 31, 1903, the number enrolled was greater than at any period in the Society's history. The total as given in the following table (viz. 540) is seventeen more than that on December 31, 1902, which was an advance on any previous record. The present total is the more gratifying, as the losses from death, resignation, and other causes during the year, amounted to 27. The number of members and associates elected during the year reached the satisfactory total of 44.

Membership.

The following table shows the numbers on the roll of the Society at the end of 1903, and the two preceding years.

Class.	Dec. 31, 1901.	Dec. 31, 1902.	Dec. 31, 1903.
Honorary Members	20	20	20
Ordinary Members	252	273	287
Ordinary Associates	122	120	118
Foreign Members	69	78	87
Foreign Associates	30	32	28
Totals	493	523	540

Finance.

The accompanying statement of accounts (see pp. 239 and 240) shows that in the important matter of finance the progress of the Society has been of a gratifying character. Notwithstanding the extra expense entailed by the visits and annual dinner, also the amount of arrears of subscription written off, the excess of income over expenditure gives the satisfactory sum of 77*l*. 12*s*. 11*d*. towards the accumulated fund. This fund (representing the cash assets of the Society) now amounts to nearly 700*l*. Of this, about 650*l*. is invested in railway stock, the interest from this investment forming an appreciable addition to the annual income.

PAPERS READ.

The following is a list of papers read during the year :—

Feb. 2.—The President's Inaugural Address. By Mr. J. Patten Barber.
March 2.—Road Traffic in and near large cities. Topical Discussion, opened by Mr. W. Worby Beaumont, Past-President.
April 6.—Road Maintenance and Administration. By Mr. Robert J. Thomas.
May 4.—Certain vexatious and fallacious Cement Tests now in vogue. By Mr. D. B. Butler, Vice-President.
June 8.—Electric Light Stations, their Design and Arrangement. By Mr. E. R. Matthews.
Oct. 5.—Motor Transport for Goods. By Mr. Douglas Mackenzie.
Nov. 2.—Bacterial Treatment of Sewage. By Mr. G. Thudichum.
Nov. 30.—Mechanical Stokers for Electricity Generating Stations. By Mr. Albert Gay.

PREMIUMS.

The Council have awarded Premiums to the following authors for the papers named in the foregoing list, viz. :—

1. To Mr. Douglas Mackenzie, the President's Gold Medal.
2. To Mr. Robert J. Thomas, the Bessemer Premium of Books.
3. To Mr. Albert Gay, a Society's Premium of Books.

ATTENDANCES AT ORDINARY MEETINGS.

It is satisfactory to find that the attendances at the ordinary meetings have improved during the past year, the average having been over 72 per meeting, as against an average of 57 per meeting in the previous year. The good attendance of visitors also is an indication of the value and interest of the papers read.

VISITS TO WORKS.

During the vacation the usual visits to works were made, and, judging by the attendances, were much appreciated. The following is a list of the works visited :—

June 24.—To the Works of Messrs. J. and E. Hall, Dartford, Kent, where the manufacture of ice-making and cold storage plant was witnessed, a practical demonstration being given.

July 22.—To the Works of the New Admiralty Harbour at Dover, in course of construction.
Sept. 23.—To the Electricity Generating Station, and one of the Baths and Wash-houses, of the Islington Borough Council.

In every instance the members were most cordially received. The council desire to impress upon the junior members and associates the practical value of these visits to works, and to point out the desirability of attending them whenever circumstances permit.

ANNUAL GENERAL MEETING.

On December 14 was held the forty-ninth Annual General Meeting of the Society, and the report of the proceedings appears in the 'Transactions.'

ANNUAL DINNER.

The forty-ninth Annual Dinner was held at the Hotel Cecil on Wednesday, December 16, and proved very successful. Among the visitors present were Mr. W. H. Mahoney Christie, M.A., Astronomer Royal; Mr. J. H. Wicksteed, President of the Institution of Mechanical Engineers; Mr. Robert K. Gray, President of the Institution of Electrical Engineers; and Councillor Charles Crole-Rees.

EXCHANGE TRANSACTIONS.

The Society continues the exchange of Transactions with the following Institutions, the volumes being available for reference by Members and Associates at the Society's offices.

The Institution of Civil Engineers.
The Institution of Mechanical Engineers.
The Institution of Electrical Engineers.
The Institution of Naval Architects.
The Iron and Steel Institute.
The Surveyors' Institution.
The Civil and Mechanical Engineers' Society.
The Junior Institution of Engineers.
The Institution of Mining and Metallurgy.
The Royal Engineers' Institute.
The Incorporated Institution of Gas Engineers.
The Royal Institute of British Architects.
The Society of Arts.
The Liverpool Engineering Society.
The Cleveland Institution of Engineers.
The North East Coast Institution of Engineers and Shipbuilders.
The North of England Institute of Mining and Mechanical Engineers.
The South Wales Institute of Engineers.
The Institution of Engineers and Shipbuilders in Scotland.
The Institution of Civil Engineers of Ireland.
The French Institution of Civil Engineers.
The Canadian Civil Engineers' Society.
The Victorian Institute of Engineers.
The Engineering Association of New South Wales.
The American Society of Civil Engineers.
The Association of Engineering Societies.
The Smithsonian Institution.
The Franklin Institute.

JOURNALS AND MAGAZINES.

The library contains many books on engineering subjects, and, in addition, the following journals and magazines are supplied gratuitously by their respective publishers; all being available for reference by the Members.

American Machinist.
American Machinery.
Arms and Explosives.
Automotor.
British Architect.
Building News.
Builder.
Commerce.
Colliery Guardian.
Contract Journal.
Cassier's Magazine.
Electrical Review.
Electrician.
Engineer.
Engineering.
Engineering Magazine.
Engineers' Gazette.
Electro-Chemist and Metallurgist.
El Ingeniero Español.
Invention.
Indian Engineering.
Indian and Eastern Engineer.
Journal of Gas Lighting.
Local Government Journal.
L'Automobile.
Machinery Market.
Marine Engineer.
Mechanical World.
Mechanical Engineer.
Mechanical Progress.
Page's Magazine.
Public Health Engineer.
Railway Official Gazette.
Surveyor.
Sanitary Record.
Shipping World.
Society of Arts Journal.
The Quarry.
The Street.
The Tramway and Railway World.
Water.

The council, in conclusion, would remind the members that next year will be the Jubilee of the Society, which was founded in 1854. They therefore purpose taking steps to celebrate its Fiftieth Anniversary in a suitable manner. The precise form of this celebration must, as a matter of course, be left to the council for 1904. But whatever may be decided upon, it is hoped that the members generally will loyally support the council so as to render successful their efforts to promote the interests of the Society.

The council would point out that there are several ways in which the members can second their efforts. The first is by personally contributing, or otherwise by obtaining, papers embodying the most recent phases of engineering practice. The next is by attending the meetings as frequently as possible and taking part in the discussions, and also by joining in the Vacation Visits. Another and most important means of giving a distinctive feature to the Jubilee of the Society and marking it as a record year, is by the introduction of new members. The council trusts that every member will aid in bringing about this desirable end by introducing gentlemen duly qualified for election, either as members or associates.

January 1904.

Dr. INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1903. Cr.

EXPENDITURE.

	£	s.	d.
To Printing Transactions, *less* Sales	146	13	7
„ Rent of Offices and Hire of Rooms	122	16	0
„ Salary of Secretary	250	0	0
„ Stationery and General Printing	41	6	3
„ Reporting Meetings	16	14	6
„ Refreshments for Members at Ordinary Meetings..	9	14	6
„ Fuel, Lighting, Office Cleaning and Repairs.. ..	14	11	11
„ Postage, Telegrams, Carriage, and General Expenses	53	15	2
„ Bad Debt Reserve Account	50	0	0
„ Vacation Visits and Dinner deficiency	18	0	9
	723	12	8
„ Balance carried to Accumulated Fund— Excess of Income over Expenditure for the year ended 31st December, 1903	77	12	11
	£801	5	7

INCOME.

	£	s.	d.	£	s.	d.
By Subscriptions for the Year	£750	4	6			
Less allowances and Bad Debts ..	42	10	6			
				707	14	0
„ Life Subscriptions—proportion for 1903				7	14	7
„ Admission Fees				63	0	0
„ Interest on Deposits				3	5	0
„ Interest on Investments				19	12	1
				£801	5	7

LIFE MEMBERSHIP FUND.

	£	s.	d.
To Revenue Account—proportion for the year 1903 ..	7	14	7
„ Balance to be carried to next Account	69	11	2
	£77	5	9

	£	s.	d.
By Balance brought from last Account, being the unexhausted Balance of the Fund on 31st December, 1902	77	5	9
	£77	5	9

PREMIUM FUND.

	£	s.	d.
To Premiums	14	5	9
„ Balance to be carried to next Account	24	15	2
	£39	0	11

	£	s.	d.
By Balance brought forward from 31st December, 1902	23	5	5
„ President's Donation	10	10	0
„ Interest to date, propn. Bessemer Trust Fund Investment	5	5	6
	£39	0	11

BALANCE SHEET, 31st DECEMBER, 1903.

LIABILITIES.

				£	s.	d.
Sundry Creditors				130	1	4
Life Membership Fund				69	11	2
Premium Fund				24	15	2
Subscriptions Paid in Advance				28	17	6
Accumulated Fund:—						
Balance at 31st December, 1902	£694	3	1			
Add Excess of Income over Expenditure for the year ended 31st December, 1903	77	12	11			
				771	16	0
				£1025	1	2

ASSETS.

				£	s.	d.
Subscriptions in Arrear	£201	15	0			
Admission Fees in Arrear	6	16	6			
	208	11	6			
Less reserved for Bad Debts	100	0	0			
				108	11	6
Cash at Bank	140	19	6			
Less due to Secretary	1	1	7			
				139	17	11
Investment—£606 L. & N. W. Ry. Co. 3 per cent. Debenture Stock				647	4	2
Office Furniture				35	0	0
Library				40	0	0
Stock of Transactions				37	14	6
Sundry Debtors				16	13	1
				£1025	1	2

Note.—£185 North Eastern Railway Stock is held in Trust to secure payment of the late Sir Henry Bessemer's Premium.

Audited and found correct,
(Signed) SAMUEL WOOD, F.C.A., *Hon. Auditor*,
30 Gracechurch Street,
London, E.C.

10*th February*, 1904.

SOCIETY OF ENGINEERS.

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